P O W E R

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Editor

POWER SERVES PROCESS

We here introduce a special section devoted exclusively to the process applications of the power services—cold water, hot water, steam, refrigeration, electricity, compressed air, controlled atmosphere, mechanical power. To the best of our knowledge this is a unique undertaking.

Every manufacturing process has its experts and specialists. Much highly detailed information on specific processes has been published, yet we can find no book, or other publication, that assembles the fundamentals of all the power services as applied to all types of processes.

In setting out to do just that in 36 pages, we have, some will say, attempted the impossible. And that would be true if one should expect to learn here how to make paper or sugar, or discover the proper conditions for dyeing silk or producing sulphuric acid. Sugar refining alone, or almost any other complex process you might name, would fill the entire section and still not tell the whole story.

Nothing of the sort is attempted here. We aim, rather, to summarize—in simple statements, sketches, charts and tables—those service-to-process fundamentals that apply everywhere, like death and taxes.

As we gather and present this material we have in mind a picture of the average process plant, and in it two key technical men—one the process engineer, the other the power engineer. The genius and experience of this process engineer is concentrated on the process itself. He studies his raw materials and plans their transformation to intermediate or final products through the application of heat, cold, agitation, pressure and so on. During this planning he may find it necessary to consult the power engineer on service possibilities. When process plans are complete he must turn again to the power man for actual delivery of the services, suitably connected, controlled and measured.

This application, unfortunately, is not simply a matter of running up lines for the necessary services. If steam is needed, how much and at what pressure? How much water is needed, and how hot? Would lower-pressure steam or cooler water serve the process equally well at lower cost? And so on.

The point is that no Chinese Wall divides process engineer and power engineer at the point of service application. What each is doing affects the other. If waste and confusion are to be avoided the two must sit down together and talk the job over.

This section may be pictured as the primer of a common language for use on such occasions. We hope that it will help power men in industry to cooperate effectively with process engineers to improve the quality of America's manufactured products, and reduce their cost.

Major subdivisions of this section, each indicated by a change of color, start as follows: pg. 642, "Basic Services"; pg. 653, "Basic Operations"; pg. 657 "Basic Equipment"; pg. 665 "Basic Service Elements"; pg. 669 "Practical Applications."

BASIC POWER SERVICES

• **THE first step in understanding the service-process applications is to understand the services themselves. The following eight articles review their fundamentals, one at a time: cold water, hot water, steam, refrigeration, electricity, compressed air, controlled atmosphere, mechanical power.**

Since this section is concerned with applications only, nothing is said about generation. We start with the service readymade, look at it and consider its properties.

Although most of POWER'S readers are fairly familiar with all of the power services and often expert in several of them, it seemed best to present each service in condensed handbook style. Steam is an endless subject, yet its major process fundamentals can be summarized in two pages. The same is true, more or less, of the other services. The reader who makes allowances for the limitations of condensation will find here much of value in reviewing the familiar services and getting some basic understanding of the others.

Here are attempts at brief scientific definitions of each power service, with statements of the factors determining quality and the measures of quantity. All, it should be remembered, refer to service in transit, not to generations.

▼

WATER *Definition:* Liquid H_2O.

Quality factors: Temperature, pressure, dissolved solids, dissolved gases, suspended solids.

Quantity measures: Pounds, gallons, cubic feet.

STEAM *Definition:* Gaseous H_2O.

Quality factors: Pressure, temperature (or superheat), moisture (liquid water), solid impurities, gaseous impurities.

Quantity measures: Pounds, or thousands of pounds.

REFRIGERATION *Definition:* Graphically, but perhaps unscientifically, refrigeration may be defined as "fluid cold." In common parlance, a fluid is "cold" when its temperature is considerably below that of the naturally available water or air. The "refrigeration" may refer to the cold *fluid* itself or to the heat it picks up in the cooling application.

Quality factors: Chemical composition, pressure, temperature, "moisture" and impurities of the *medium* used to convey the refrigeration (not necessarily the same as the *refrigerant* used in generating the refrigeration).

Quantity measures: Since there is no absolute standard of "cold," refrigeration measures always involve a *difference* of temperatures or a *difference* of heats. The measure of the actual refrigeration delivered to a process or department is the pounds of refrigerating medium passed through the process or department multiplied by the *difference* between the heats per pound entering and leaving the process or department. If this rate of delivering refrigeration happens to be 288,000 B.t.u. per 24 hrs., it is said to be a "ton" of refrigeration, since this is the heat removed from a ton of water at 32 F to produce a ton of ice at 32 F.

ELECTRICITY *Definition:* A scientific definition is difficult and of little value, hence this practical definition: Electricity is that invisible something which produces heat and magnetic effects when it flows through metal, and produces heat and chemical changes when it flows through solutions.

Quality factors: Volts, voltage uniformity, d.c. or a.c., cycles or frequency, uniformity of frequency, number of phases, power factor.

Quantity measures: Amperes (rate of flow of electricity), watts or kilowatts (power); ampere hours (quantity of electricity), watt-hours and kilowatt-hours (quantity of energy).

COMPRESSED AIR *Definition:* Air at pressures substantially above atmospheric. (Air delivered from fans or positive blowers at pressures only slightly above atmospheric is not generally called "compressed air")

Quality factors: Pressure, temperature, relative humidity, moisture (liquid), dirt and other solid impurities, gaseous impurities.

Quantity measures: Cubic feet of free air; that is, actual cubic feet of compressed air figured back to the volume it would occupy at atmospheric pressure and 60 F. Also pounds.

CONTROLLED ATMOSPHERE *Definition:* A conveyed supply of uncompressed air specially heated, cooled, dried, moistened or cleaned (or several of these).

Quality factors: Temperature, pressure (occasionally), humidity, dirt and other solid impurities, gaseous impurities.

Quantity measures: Cubic feet, pounds. May also be measured in terms of pounds of water it can remove in drying operations.

MECHANICAL POWER *Definition:* Considered as a service, mechanical power is the flow of energy through solid machine members (gears, shafts, pulleys, belts, chains, sprockets, etc.) in the form of moving mechanical forces.

Quality factors: Force, distance moved, velocity, torque, angular movement, revolutions per minute.

Quantity measures: The foregoing lump mechanical "power" and "work," as is customary in power-plant speech. Scientifically, the energy delivered is *work*—force times distance, measured in foot-pounds. *Power*, the rate of doing work, or the *rate* of delivering energy, is measured in foot-pounds per minute or per second or in horsepower (1 hp. = 33,000 ft.-lb. per min. or 550 ft.-lb. per sec.).

1. COLD WATER

WATER, most important engineering substance, and a primary power service, is H_2O (Fig. 1). Molecule contains 2 atoms hydrogen, 1 atom oxygen. By volume, water is 2 parts H and 1 part O; by weight, 1 part H and 8 parts O.

A given batch of commercial water is completely described by its pressure, temperature and impurities (dissolved solids, suspended solids, dissolved gases). Solid impurities are measured in grains per gallon (gr.p.g.) or in parts per million (p.p.m.). 1 gr.p.g. equals 17.2 p.p.m. Dissolved gases are measured in cc of gas per 1,000 c.c. of water.

DENSITY, HEAT, PRESSURE At 60 F, 1 cu. ft. of water weighs 62.4 lb. Since 1 cu. ft. = 7.481 gal., 1 gal. weighs 8.34 lb. These figures apply to all temps. from 32 F to 100 F, with error not exceeding 1%. Up to 80 F, the error does not exceed 1/3%. Fig. 1, page 644, gives correct densities for temps. from 32 F to 600 F.

TANK CAPACITIES Table I gives capacity of cylindrical tanks per inch of length. If tank is horizontal and partly full, apply the fullness factor given.

WATER AT REST At 60 F (and approximately from 32 F to 100 F), 1 lb. per sq.in. = 2.31 ft. of head, and 1 ft. of head = 0.433 lb. per sq.in. In water at rest pressure at any depth below free surface equals pressure at surface plus 0.433 lb. per sq.in. for each foot of depth. (Fig. 1 on next page gives depth factors for hot water.)

Problem: Air pressure over water in tank is 55 lb. gage. Water temperature is 60 F. What is pressure 7 ft. below surface?

Solution: Added pressure for 7 ft. = 7 × 0.433 = 3 lb. +

Total pressure = 55 + 3 = 58 lb. gage.

Problem: An open-ended vertical pipe is connected below the water level in a tank subjected to 10 lb. air pressure. How high will water (at 70 F) rise in the pipe?

Solution: 10 × 2.31 = 23.1 ft. rise above tank water level.

WATER IN MOTION If water flows steadily along a pipe without friction, hydraulic gradient remains constant (*A* in Fig. 2). Since all pipes have friction, the actual hydraulic gradient falls as in *B*. Note that pressure gages on the pipe do not show friction drop directly unless pipe is level. E.g., if gage *d* reads 20 lb. less than *c*, and is 10 ft. lower, friction drop is 20 lb. plus 4.3 = 24.3 lb. Here the 4.3 lb. corrects for the 10 ft. difference in gage level.

Constriction in pipe (Fig. 3) increases velocity and lowers hydraulic gradient. Except for friction loss, original hydraulic gradient is regained when pipe enlarges to original diameter. In short, neglecting friction, "static head" plus "velocity head" is constant. To keep friction low, constriction should be streamlined.

PIPING FORMULA Table II gives a simplified formula (with tables of constants) for figuring flow of water through "standard" pipe, for any desired pressure drop per thousand feet. Problem illustrates application.

ORIFICE FORMULAS Orifices are conveniently used to measure water flow where pressure or head across orifice can be measured. The general formula is: $Q = F \times A \times 8.02 \times \sqrt{H}$, where Q is cu.ft. per sec., F is orifice factor or discharge coefficient, A is orifice area in sq.ft., H is difference in head in ft., F is 0.61 for a sharp-edged or thin-plate orifice and 0.96 for a parallel-throat orifice with well rounded entrance. These factors apply to tank orifices, also to metering orifices in pipes if orifice diameter is not over half pipe diameter and pressure taps are 1 pipe diameter upstream and ½ pipe diameter downstream. The data sheet on page 678 charts this formula. For other orifices or other conditions refer to handbooks or run test to get correct coefficients.

The simple formula of Fig. 4 can be applied to any orifice without measuring area or considering shape or connections. K is found by simple test. For example, the spray head shown is found to deliver 1,030 gal. per hr. when pressure gage reads 100 lb. Then $K = 1{,}030 \div \sqrt{100} = 103$. Therefore, formula for this spray is: Gal. per hr. = $103\sqrt{\text{pressure}}$. Use this to compute and plot a "calibration curve." From this curve, in turn, one may prepare (for pasting on the gage face) a scale reading gal. per hr. directly.

Table I—Capacity of Cylindrical Tanks per Inch of Length

Dia., In.	Cu. Ft.	Gal.	Lb. Water 60 F.
10	.0454	.340	2.835
12	.0654	.490	4.08
14	.0891	.667	5.56
16	.1163	.870	7.25
18	.1472	1.102	9.18
20	.1818	1.360	11.34
25	.2841	2.125	17.72
30	.4091	3.060	25.52
35	.5567	4.165	34.72
40	.7272	5.440	45.36
45	.9204	6.885	57.41
50	1.136	8.500	70.85
55	1.375	10.28	85.76
60	1.636	12.24	102.0
65	1.920	14.36	119.8
70	2.227	16.66	138.9
75	2.557	19.12	159.5
80	2.91	21.8	181.
85	3.28	24.6	205.
90	3.68	27.5	230.
95	4.10	30.7	256.
100	4.55	34.0	284.

NOTE: To get total equivalent length of straight tank add, to full-diameter length of tank, ⅔ the depth of the bumped (elliptical) heads.

Capacity Factors for Horizontal Cylindrical Tanks Partly Full

Percent full by depth	5	10	15	20	25	30	35
Percent full by volume	2	5	9	14	20	25	31

40	45	50	55	60	65	70	75	80	85	90	95
37	44	50	56	63	69	75	80	86	91	95	98

NOTE: While computed for flat-end tanks only, the above factors will be close enough for most practical purposes with bumped-end tanks.

Table II—Formula for Flow of Water in Pipes

(Simplification of Manning Formula)

Rate of Flow equals AxBxCxD (whose values are given below)

VALUES OF "A"

For Rate of Flow Expressed In:	Value of A is
Gal. per min	0.0132
Cu. ft. per min	0.00177
Lb. per min	0.11
Gal. per hr.	0.79
Cu. ft. per hr.	0.106
Lb. per hr.	6.6

VALUES OF "B"

New brass pipe	10
New pipe (steel, w.i. or c.i.)	8
New galvanized pipe	6
Old and corroded iron or steel pipe	3

VALUES OF "C" FOR STANDARD PIPE

Nominal Size, Inches	"C"	Nominal Size, Inches	"C"	Nominal Size, Inches	"C"
1	1.1	3	20	12	770
1¼	2.3	3½	30	14	1100
1½	3.5	4	40	16	1600
2	7.0	5	75	18	2200
2½	11.5	6	122	20	3000
		8	260		
		10	480	24	5000

VALUES OF "D"

(Depending on pressure drop in lb. per sq. in., per 1,000 ft. of pipe)

Drop, Lb. per Sq. In.	"D"	Drop, Lb. per Sq. In.	"D"	Drop, Lb. per Sq. In.	"D"
1	10	14	37	70	84
2	14	16	40	80	89
3	17	18	42	90	95
4	20	20	45	100	100
5	22	25	50	120	110
6	25	30	55	140	118
7	26	35	59	160	127
8	28	40	63	180	134
9	30	45	67	200	142
10	32	50	71	300	174
12	35	60	77	400	200

Problem: How many pounds of water per hour will be delivered by a 4-in. galvanized new pipe 600 ft. long with a pressure drop of 24 lb.?

Solution: Drop per 1,000 ft. = 24 ÷ 0.6 = 40 lb.

Then A is 6.6, B is 6, C is 40, D is 63.

Lb. per hr. equals 6.6x6x40x63 equals 100,000 lb. per hr.

(Slide-rule accuracy is more than sufficient for this formula, since unknown variations in pipe surface may introduce errors of 10% +)

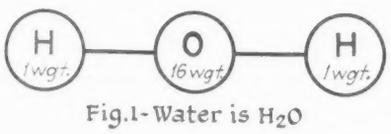


Fig. 1-Water is H_2O

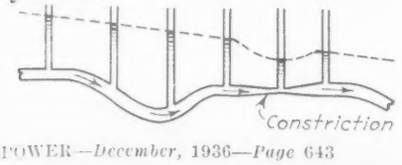


Fig. 3-"Venturi" constriction momentarily speeds up flow and lowers hydraulic gradient

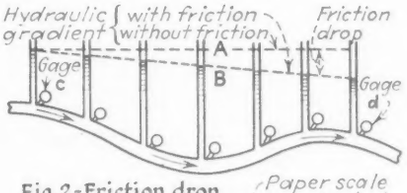


Fig. 2-Friction drop is proportional to pipe length

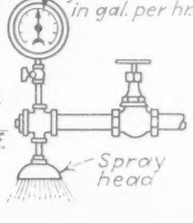


Fig. 4-Simple formula for any orifice is: Discharge = $K\sqrt{\text{press. diff.}}$

2. HOT WATER

FOR convenience, hot water is here treated as a separate service, although the line of demarcation between "hot" and "cold" water depends on conditions and point of view. From the power-service angle, hot water is water specially heated to at least 100 F., generally considerably higher. It therefore costs more than cold water and should be considered a separate service for accounting purposes.

Practically all the information under "Cold Water" (preceding page) applies also to hot water. Conversely the heat relations here shown, and used mainly in connection with hot water, apply also to cold.

DENSITY As temperature rises from 32 F. to 100 F., density falls very slightly—above 100 F., more and more rapidly. Scales *A* and *B*, Fig. 1, give density in lb. per cu.ft. and per gal., respectively, for all temperatures from 32 F. to 600 F.

Problem: How many pounds of water at 320 F. will be contained in a 50-in. diameter tank, if cylindrical part is 80 in. long and there are two 12-in. bumped heads?

Solution: (See Fig. 2, previous page). Two bumped heads = $\frac{2}{3} \times 24 = 16$ in. of cylindrical tank. Equivalent total length = $80 + 16 = 96$ in. Volume per in. of length is 1.136 cu.ft. Total volume = $96 \times 1.136 = 109$ cu.ft. Weight of water per cu.ft. at 320 F. (*A*, Fig. 1) = 56.7 lb. Total contents = $109 \times 56.7 = 6{,}180$ lb.

While 0.433 lb. per sq.in. per foot of head is a sufficiently accurate factor for conversion between head and pressure with water from 32 F. to 80 F., and fairly close up to 100 F., it should not be used for hot water. *C* in Fig. 1 gives the correct factors.

Problem: A column of water at 350 F. (Fig. 2) is under a steam pressure of 121 lb. gage. What is pressure 26 ft. below surface?

Solution: Surface pressure = 121 + 15 = 136 lb. abs. From *D*, Fig. 1, saturation temperature is 350 F. (approximately), showing that conditions given are possible. From *C*, conversion factor is 0.387 lb. per sq.in. Then 26 ft. = $26 \times 0.387 = 10$ lb. Total gage pressure at 26-ft. depth = 121 + 10 = 131 lb.

SATURATION TEMPERATURES Scale *D* gives the absolute saturation (boiling) pressure for all temperatures. Scale *E* repeats the lower ranges on a larger scale. More on this subject will be found under "Steam" page 645. The practical point here is that the pressure over the water cannot be less than this saturation pressure, although it may be more. Any attempt to lower the pressure below this point will result in "flashing." This is particularly important in pumping.

Fig. 3 shows what would happen if water at 180 F. is lifted by a piston sliding in a long tube. As the piston rises, suction increases and absolute pressure (at the surface of the water in the tube) falls until the level reaches 17 ft. and the absolute pressure falls to 7.5. As that point the column comes to rest, while the piston moves on up. A slow-moving piston is assumed. In practice, 180 F. water cannot be pumped 17.1 ft. by suction, because there is no remaining suction to take care of flow friction. Practical lifts of hot water are less than the theoretical by from 5 to 20 ft. or more, depending on piping, pump design, speed of pumping, etc.

HEAT PROBLEMS *One British thermal unit (B.t.u.) is the average heat required to raise temperature of one pound of water one degree F.* in range from 32 F. to 212 F. For process work, 1 B.t.u. per degree is close enough anywhere between 32 F. and 250 F. Above 250 F. refer to the steam table (page 645).

At any temperature between 32 F. and 250 F., *Heat added or subtracted (in B.t.u.) equals weight of batch of water times temperature rise or fall.* Many processed materials (e.g., soup) are mainly water and follow the same rule approximately. Thus, to heat 2,000 lb. of thin soup from 60 F. to 250 F. takes $190 \times 2{,}000 = 380{,}000$ B.t.u. approximately.

To get the final temperature when two batches of water at different temperatures (or a batch of water and a batch of soup) are mixed, use this rule: Multiply weight of each batch by its temperature. Add the products and divide by weight of final batch. Thus (Fig. 4) 1,600 lb. of water at 60 F. plus 2,000 lb. at 180 F. gives 3,600 lb. at 126.6 F.

To solve such problems by steam-table data (page 645) use this rule: *Heat gained by cold batch equals heat lost by hot batch.* This applies also where a batch of water is heated by a batch of steam, as will be shown on page 645.

Where the steam is mixed directly with the water, a simple rule is: *Heat in the batch of cold water plus heat in the batch of steam equals heat in the final heated batch.* For very rough estimates, merely figure that each pound of condensing steam supplies 1,000 B.t.u.

Problem: How much steam will it require to heat 1,400 lb. of dye solution from 60 F. to 200 F.

Solution: Heat required = $(200 - 60) \times 1{,}400 = 196{,}000$ B.t.u. $196{,}000 \div 1{,}000 = 196$ lb. steam needed.

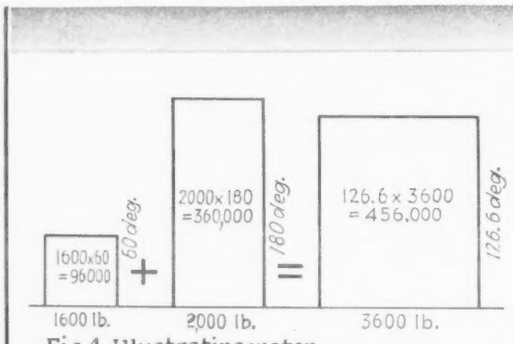


Fig.4-Illustrating water-mixing problem (see text)

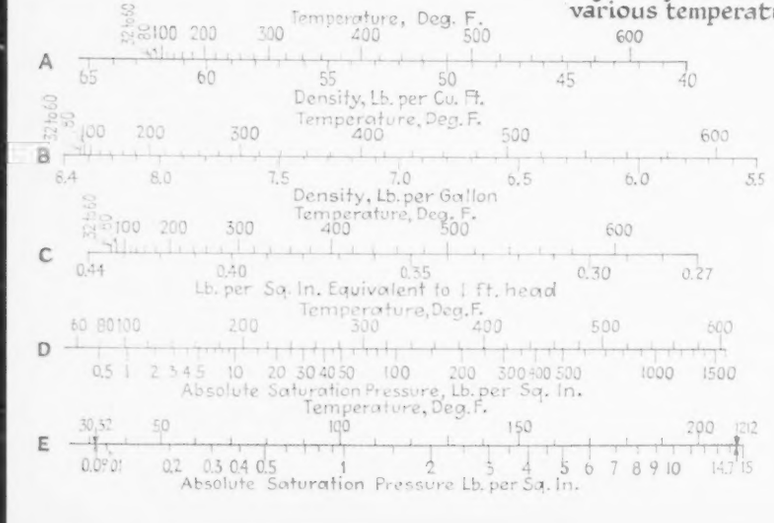


Fig.1-Properties of water, various temperatures

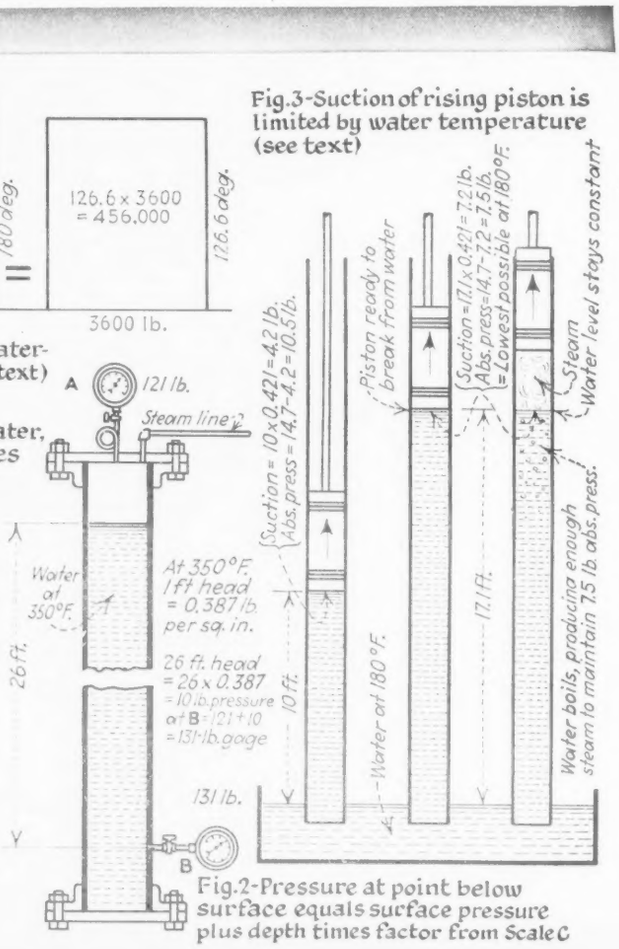

A
121 lb.
Steam line
Water at 350°F.
At 350°F. 1 ft head = 0.387 lb. per sq. in.
26 ft. head = 26 × 0.387 = 10 lb. pressure at B = 121 + 10 = 131 lb. gage
26 ft.
10 ft.
131 lb.
B
Water at 180°F.
Piston ready to break from water
17.1 ft.
Steam
Water level stays constant
Water boils, producing enough steam to maintain 7.5 lb. abs. press.

Fig.2-Pressure at point below surface equals surface pressure plus depth times factor from Scale C

Fig.3-Suction of rising piston is limited by water temperature (see text)

3. STEAM

STEAM is water in the form of a vapor or imperfect gas. "Saturated" steam is steam at the boiling temperature corresponding to the existing pressure. When water, heated under constant pressure, reaches the saturation temperature it starts to boil, thereby preventing further temperature rise, as long as pressure is held constant. The steam over the water will also be practically "saturated," that is, at the boiling temperature. Steam at higher temperature is called "superheated." It is difficult to superheat steam appreciably if close to the surface of water. Taken away from the water, the steam can be superheated to any desired temperature without increase of pressure.

The most valuable technical tool of the steam engineer is the "Steam Tables." These give, for all pressures, the properties of saturated liquid (liquid at the boiling temperature), saturated vapor and superheated vapor. Every engineer should have a copy of the unabridged steam tables. The abridged table shown in Fig. 6, is too short for convenient general use, but will illustrate the use of the unabridged tables. "Entropy" columns have been omitted. Note that all pressures in the table are absolute. Absolute pressure = gage pressure plus 14.7 lb. (15 lb. is generally close enough).

Thus, at 100 lb. abs. (85.3 lb. gage) water boils at 327.81 F., producing steam at the same temperature. This is the saturation temperature. The pound of saturated water occupies 0.01774 cu. ft. and increases to 4.432 cu. ft. when it turns into saturated steam. If this steam is removed from contact with the water and superheated at the same pressure to 400 F. total temperature, its volume will be 4.937 cu. ft. The superheat will be 400-327.8 = 72.2 F. At 700 F. the steam volume will be 6.835 cu. ft. Thus superheated steam at constant pressure expands with rising temperature, much like heated air, but not in exact proportion to the absolute temperature, as would a true gas.

"Enthalpy" is the quantity still widely known as "heat" in such expressions as "heat of liquid" etc. Except in the table itself, the "heat" terminology will be used throughout this article.

The table shows that when water at 100 lb. abs. is heated from 32 F. to 327.8 F., the heat supplied is 298.7 B.t.u. To turn the saturated liquid into saturated steam takes another 888.2 B.t.u., giving a total heat of 1187.2 B.t.u. for the saturated steam. Superheating to 400 F. brings this total heat (above 32) to 1227.6 B.t.u. Heating to 700 F. makes it 1378.9 B.t.u.

If the superheated steam, at 700 F., is put in a container where it can gradually give up heat without losing pressure, these heats will be given out in the reverse order, as the steam first cools to saturation, then condenses and cools to 32 F.

Processes practically never cool condensate to 32 deg. F. If not, the heat given up to the process by a pound of steam is the difference between the initial heat of the steam and the heat of the condensate as it leaves the kettle or other process equipment.

Example: Process steam at 20 lb. absolute and 400 F. is supplied to a jacketed kettle. Condensate leaves for the trap at 210 deg. How much heat does each pound of steam deliver to kettle (neglecting radiation)? Neglect decimal parts.

Solution: Heat of initial steam = 1239 B.t.u. Heat of condensate 210 — 32 = 178 Bt.u. Heat delivered = 1239—178 = 1061 B.t.u. Heat of condensate may be taken directly from the complete steam tables, but T-32 is close enough for all temperatures up to 250 F.

Note that the heat per pound of saturated steam increases slightly with rising pressure up to about 450 lb. and thereafter gets smaller. Steam table data are plotted in Figs. 1, 2, 3, 5 and 7 to avoid interpolating in Fig. 6, where complete tables are not available.

HEATING WATER WITH STEAM—In process applications, steam may heat water by direct contact or by heat transfer through metal. In direct-contact heating, steam is bubbled into the water or solution to be heated. The condensate becomes part of the process water and the available heat of the steam is fully utilized. In this case the total heat of the resulting mix-

Fig. 4-(Top) Constant-pressure heating, evaporation of water and superheating

Fig. 5-(Bottom) Graphical table for saturate water and steam

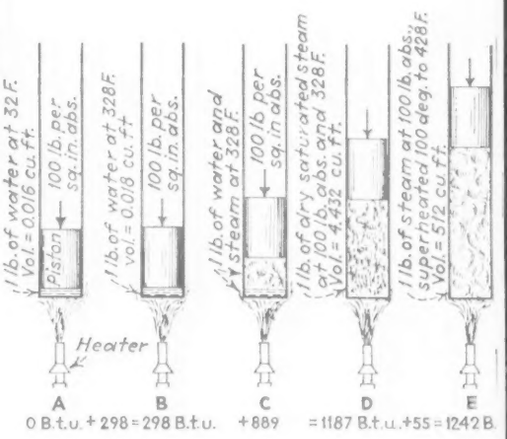
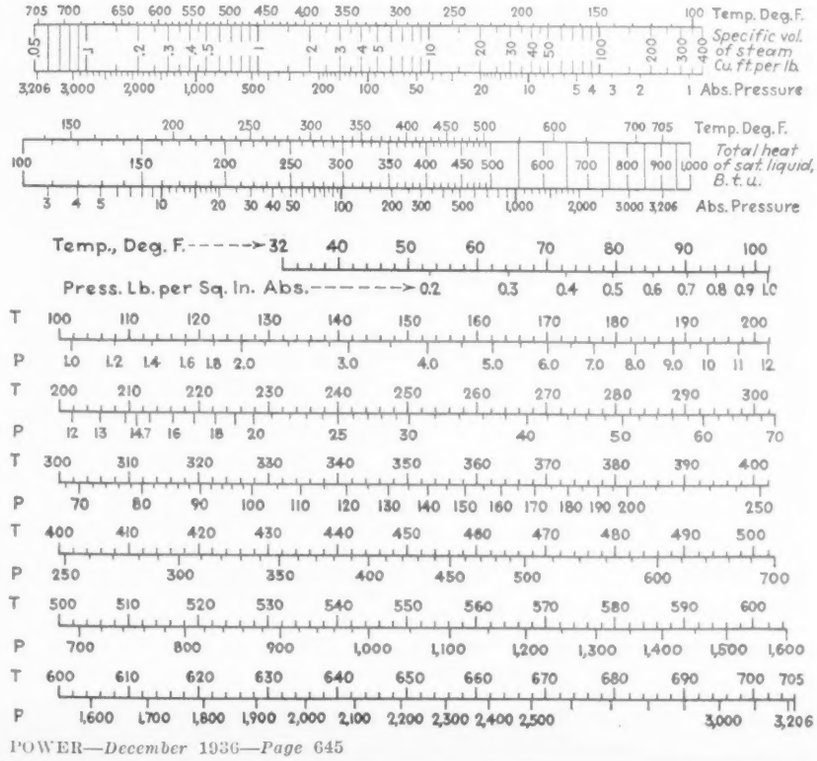
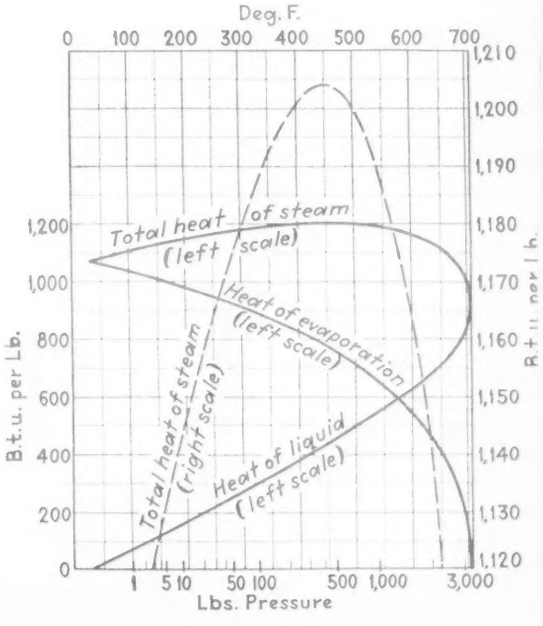

1 lb. of water at 32 F. Vol. = 0.016 cu. ft.
Piston
100 lb. per sq. in. abs.
1 lb. of water at 328 F. Vol. = 0.018 cu. ft.
100 lb. per sq. in. abs.
1 lb. of water and 1 steam at 328 F.
100 lb. per sq. in abs.
1 lb. of dry saturated steam at 100 lb. abs. and 328 F. Vol. = 4.432 cu. ft.
1 lb. of steam at 100 lb. abs. superheated 100 deg. to 428 F. Vol. = 5.12 cu. ft.
Heater
A
B
C
D
E
0 B.t.u. + 298 = 298 B.t.u.
+ 889
= 1187 B.t.u. + 55 = 1242 B.

Fig. 1-(Top) Specific volume of saturated steam
Fig. 2-(Middle) Heat of liquid water
Fig. 3-(Bottom) Relation of pressure and temperature of saturation




Deg. F.
Total heat of steam (left scale)
Heat of evaporation (left scale)
Heat of liquid (left scale)
Total heat of steam (right scale)
B.t.u. per Lb.
B.t.u. per Lb.
Lbs. Pressure

v=Specific volume, cu. ft. per lb.
H=Enthalpy, B. t. u. per lb.

Condensed by permission from "Thermodynamic Properties of Steam" by Keenan & Keyes, published (1936) by John Wiley & Sons, New York

Press lb. / sq. in abs.	Sat. Temp., deg. F.	Sat. Liquid	Evaporation	Sat. Steam	Superheated Steam, Temperature, deg. F. 200	300	400	500	600	700	800	900	1000	
1	101.7	.01614		333.6	392.6	452.3	512.0	571.6	631.2	690.8	750.4	809.9	869.5	V
		69.70	1036.3	1106.0	1150.4	1195.8	1241.7	1288.3	1335.7	1383.8	1432.8	1482.7	1533.5	H
2	126.1	.01623		173.73	196.1	226.0	255.9	285.7	315.5	345.4	375.1	404.9	434.7	V
		93.99	1022.2	1116.2	1150.0	1195.6	1241.6	1288.2	1335.6	1383.8	1432.8	1482.7	1533.5	H
3	141.5	.01630		118.71	130.56	150.60	170.54	190.44	210.3	230.2	250.1	269.9	289.8	V
		109.37	1013.2	1122.6	1149.6	1195.4	1241.5	1288.1	1335.5	1383.7	1432.8	1482.7	1533.4	H
5	162.2	.01640		73.52	78.16	90.25	102.26	114.22	126.16	138.10	150.03	161.95	173.87	V
		130.13	1001.0	1131.1	1148.8	1195.0	1241.2	1288.0	1335.4	1383.6	1432.7	1482.6	1533.4	H
10	193.21	.01659		38.42	38.85	45.00	51.04	57.05	63.03	69.01	74.98	80.95	86.92	V
		161.17	982.1	1143.3	1146.6	1193.9	1240.6	1287.5	1335.1	1383.4	1432.5	1482.4	1533.2	H
14.7	212.0	.01672		26.80		30.53	34.68	38.78	42.86	46.94	51.00	55.07	59.13	V
		180.07	970.3	1150.4		1192.8	1239.9	1287.1	1334.8	1383.2	1432.3	1482.3	1533.1	H
15	213.03	.01672		26.29		29.91	33.97	37.99	41.99	45.98	49.97	53.95	57.93	V
		181.11	969.7	1150.8		1192.8	1239.9	1287.1	1334.8	1383.1	1432.3	1482.3	1533.1	H
20	227.96	.01683		20.089		22.36	25.43	28.46	31.47	34.47	37.46	40.45	43.44	V
		196.16	960.1	1156.3		1191.6	1239.2	1286.6	1334.4	1382.9	1432.1	1482.1	1533.0	H
40	267.25	.01715		10.498		11.040	12.628	14.168	15.688	17.198	18.702	20.20	21.70	V
		236.03	933.7	1169.7		1186.8	1236.5	1284.8	1333.1	1381.9	1431.3	1481.4	1532.4	H
60	292.71	.01738		7.175		7.259	8.357	9.403	10.427	11.441	12.449	13.452	14.454	V
		262.09	915.5	1177.6		1181.6	1233.6	1283.0	1331.8	1380.9	1430.5	1480.8	1531.9	H
80	312.03	.01757		5.472			6.220	7.020	7.797	8.562	9.322	10.077	10.830	V
		282.02	901.1	1183.1			1230.7	1281.1	1330.5	1379.9	1429.7	1480.1	1531.3	H
100	327.81	.01774		4.432			4.937	5.589	6.218	6.835	7.446	8.052	8.656	V
		298.40	888.8	1187.2			1227.6	1279.1	1329.1	1378.9	1428.9	1479.5	1530.8	H
150	358.42	.01809		3.015			3.223	3.681	4.113	4.532	4.944	5.352	5.758	V
		330.51	863.6	1194.1			1219.4	1274.1	1325.7	1376.3	1426.9	1477.8	1529.4	H
200	381.79	.01839		2.288			2.361	2.726	3.060	3.380	3.693	4.002	4.309	V
		355.36	843.0	1198.4			1210.3	1268.9	1322.1	1373.6	1424.8	1476.2	1528.0	H
300	417.33	.01890		1.5433				1.7675	2.005	2.227	2.442	2.652	2.859	V
		393.84	809.0	1202.8				1257.6	1314.7	1368.3	1420.6	1472.8	1525.2	H
400	444.59	.0193		1.1613				1.2851	1.4770	1.6508	1.8161	1.9767	2.134	V
		424.0	780.5	1204.5				1245.1	1306.9	1362.7	1416.4	1469.4	1522.4	H
500	467.01	.0197	.9081	.9278				0.9927	1.1591	1.3044	1.4405	1.5715	1.6996	V
		449.4	755.0	1204.4				1231.3	1298.6	1357.0	1412.1	1466.0	1519.6	H
1000	544.61	.0216	.4240	0.4456					0.5140	0.6084	0.6878	0.7604	0.8294	V
		542.4	649.4	1191.8					1248.8	1325.3	1389.2	1448.2	1505.1	H
1500	596.23	.0235	.2530	.2765					0.2815	0.3719	0.4352	0.4893	0.5390	V
		611.6	556.3	1167.9					1174.5	1287.2	1363.8	1429.3	1499.1	H
2000	635.82	.0257	.1621	.1878						0.2489	0.3074	0.3532	0.3935	V
		671.7	463.4	1135.1						1240.0	1335.5	1409.2	1474.5	H
2500	668.13	.0287	.1021	.1307						0.1686	0.2294	0.2710	0.3061	V
		730.6	360.5	1091.1						1176.8	1303.6	1387.8	1458.4	H
3000	695.36	.0346	.0512	.0858						0.0984	0.1760	0.2159	0.2476	V
		802.5	217.8	1020.3						1060.7	1267.2	1365.0	1441.8	H
3206	705.4	.0503	0	.0503							0.1583	0.1981	0.2288	V
		902.7	0	902.7							1250.5	1355.2	1434.7	H

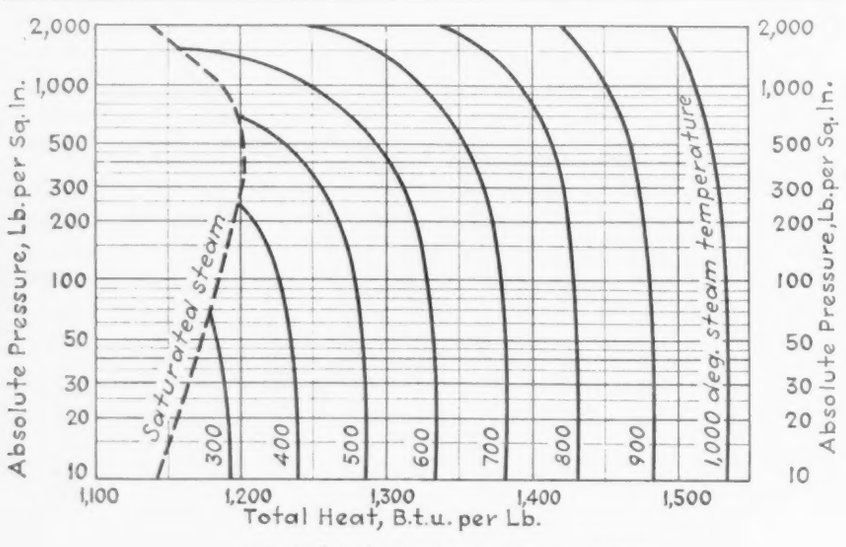


Fig.6-(Top) Condensed steam table

Fig.7-(Bottom) Heat of superheated steam

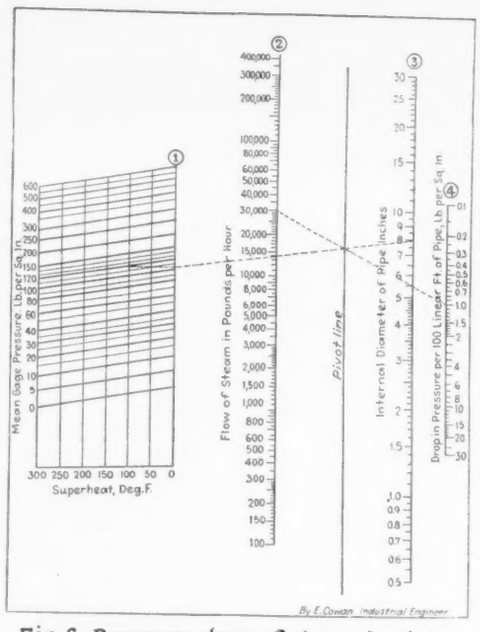

Mean Gage Pressure Lb. per Sq. In.
Superheat, Deg. F.
Flow of Steam in Pounds per Hour
Pivot Line
Internal Diameter of Pipe Inches
Drop in Pressure per 100 Linear Ft of Pipe, Lb. per Sq. In.
By E. Conan Industrial Engineer

Fig.8-Pressure drop of steam in pipes

ture of condensate and heated process water equals the sum of the total heats of the initial batches of steam and water.

Problem: 80 lb. of saturated process steam at 20 lb. abs. is absorbed by 1,200 lb. of process water at 60 F. What is final temperature, assuming no heat losses?

Solution: Heat of steam batch + heat of original water batch = heat of final batch of mixture:

$80 \times 1156 + 1200 \quad (60 - 32) = 1280 \quad (T - 32)$

$92{,}500 + 33{,}600 = 1280T - 41{,}000$

$1280T = 92{,}500 + 33{,}600 + 41{,}000$

$T = 167{,}100 \div 1280 = 131$ F.

Problem: 800 lb. of water at 70 F. is to be heated to 202 F. How much steam will be required, furnished at 20 lb. abs. and 400 deg.? (Assume no losses).

Solution:

Heat of steam + Heat of original water = Heat of final mixture

Let W = weight of steam required

$1239W + 800 \quad (70 - 32) = (800 + W) \quad (202 - 32)$

$W = 105{,}600 \div 1069 = 99$ lb. (weight) of steam

With coil or jacket heating, where condensate leaves at temperature above that of water to be heated, write the formula:

Heat lost by steam = Heat gained by water.

Weight of steam × (Heat in 1 lb. steam − Heat in 1 lb. of condensate) = Weight of water × Temperature Rise.

Fill in known quantities and solve for unknown.

Fig. 7, giving heat content of superheated steam, can also be used to show change of superheat by throttling. Heat content does not change in throttling, so move vertically downward from initial condition to final pressure and read final temp.

For example, steam at 115 abs. and 400 F. throttles to 370 F. at 15 lb. abs. Initial superheat is 62 F., final is 157 F.

Fig. 8 solves problems involving flow of steam in pipes, relating the flow and pressure drop.

Rough estimates of steam lost through holes and orifices may be made by Napier's formula: Lb. discharge per hr. = Abs. press. in lb. per sq. in. × Area of hole in sq. in ÷ 70. This applies only when final abs. pressure is less than 57% of initial.

4. REFRIGERATION

WE HERE consider refrigeration as a service already generated—as "fluid cold." The amount of refrigeration delivered is the amount of heat picked up by the medium, in B.t.u. or other units.

Common media are air, water, brine and the liquid refrigerant used in generating the refrigeration. The latter may be any one of a variety of fluids having a low boiling temperature at pressures above atmosphere. Most common is ammonia. Others widely used are carbon dioxide, sulphur dioxide, Freon, methyl chloride, ethyl chloride, trichloromethane, water. Refrigerated air is considered separately (page 651). Much of the information on page 643 will apply to water as a carrier of refrigeration. Hereafter the term "refrigerant" will be used solely to denote the medium for carrying the refrigeration to the process.

Refrigeration, in B.t.u., delivered by water, equals the pounds of cold water piped to the process times the difference in temperature between the water entering and leaving the process. With brine the refrigeration, in B.t.u., is this product times the specific heat. Water is an ideal refrigerant where temperatures are safely above 32 F. Brines can be used for temperatures as low as—60 F if sufficiently concentrated. Most commonly used are calcium chloride and sodium chloride, the former generally preferred. The table gives data on calcium chloride brine. Specific heats are averages for the usual temperature ranges. Fig. 3 gives the approximate refrigeration supplied per pound by calcium-chloride brine of any specific gravity for any temperature rise.

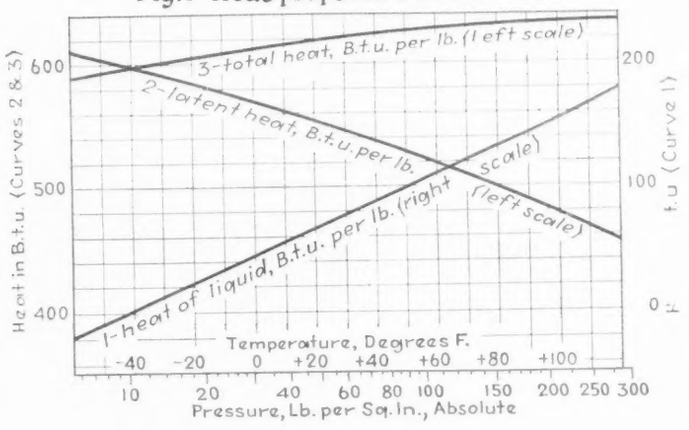
Fig. 1 and 2 will be convenient when applying ammonia directly to process in expansion coils. Fig. 1 corresponds exactly to the steam chart on page 645 and is used in the same way. Liquid ammonia is supplied to the expansion valve just before the cooling coil at saturation temperature or somewhat below (subcooled). It leaves as vapor at saturation temperature or somewhat higher (superheated). Neglecting these departures from saturation temperature, the refrigeration per pound expanding from liquid at 153 lb. absolute (80 F saturation temp.) to vapor at 23.7 lb. abs. (—10 F saturation temp.) is (from Fig. 1) 609 B.t.u. —132 B.t.u. = 477 B.t.u. per lb. Undercooling the liquid supplied adds about 1.1 B.t.u. per deg., and superheating vapor about 0.6 B.t.u. per deg. Fig. 2 gives the B.t.u. refrigeration delivered per pound for any temp. of liquid ammonia supplied and any press. and temp. of vapor removed. Remember that pressures are absolute in Fig. 1 and Fig. 2. Add 14.7 lb. to gage reading to get absolute pressure.

All refrigeration measurements can be made in B.t.u., but the term "ton" is widely used. In commercial practice, the "ton" of refrigeration is a *rate*—the abstraction of heat at the rate of 288,000 B.t.u. per 24 hr. (200 B.t.u. per min.) Power per "ton" for a single-acting compressor with 75-deg. difference of saturation temperatures (between suction and discharge) averages around 0.9 hp. (indicated). This rises about ¼ hp. for each 10-deg. rise in saturation temp. difference. Use of brine to convey refrigeration lowers the suction saturation temperature about 10 deg. and adds approximately ¼ hp. per ton.

Table—Freezing Points and Composition of Calcium Chloride Brines
(From 1936 edition of Kent's M. E. Handbook)

Specific Gravity at 68	Freezing Point	Specific Heat
1.1	+18.0	10.88
1.125	+12.5	0.87
1.150	+ 6.5	0.85
1.175	— 2.0	0.835
1.200	—12.5	0.81
1.225	—23.5	0.80
1.250	—36.5	0.77

Fig. 1-Heat properties of ammonia


3-total heat, B.t.u. per lb. (left scale)
2-latent heat, B.t.u. per lb. (left scale)
1-heat of liquid, B.t.u. per lb. (right scale)
Heat in B.t.u. (Curves 2 & 3)
600
500
400
200
100
0
t.u (Curve 1)
F
Temperature, Degrees F.
-40 -20 0 +20 +40 +60 +80 +100
10 20 40 60 80 100 150 200 250 300
Pressure, Lb. per Sq. In., Absolute

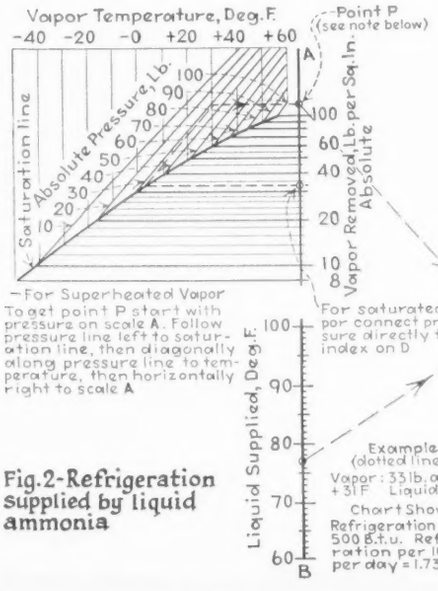
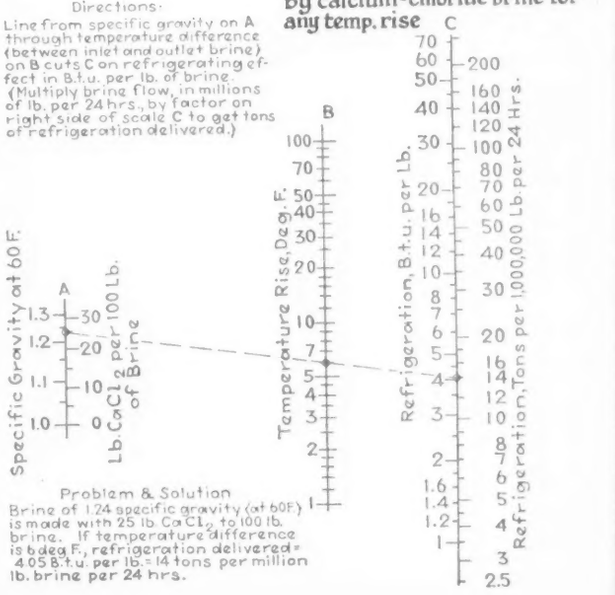

Vapor Temperature, Deg. F.
-40 -20 -0 +20 +40 +60
Point P (see note below)
Saturation line
Absolute Pressure, Lb.
100 90 80 70 60 50 40 30 20 10
A
100 60 40 20 10 8
Vapor Removed, Lb. per Sq. In. Absolute
For Superheated Vapor
To get point P start with pressure on scale A. Follow pressure line left to saturation line, then diagonally along pressure line to temperature, then horizontally right to scale A
For saturated vapor connect pressure directly to index on D
C
D
130 520 510 500 490 480 470 460 450 440 430
1.80 1.75 1.70 1.60 1.60 1.55 1.50
B.t.u. Refrigeration per Lb. Ammonia
Tons of Refrigeration per 1000 Lb. Ammonia per 24 Hrs.
Index
Liquid Supplied, Deg. F.
100 90 80 70 60
B
Example (dotted line)
Vapor: 33 lb. abs. and +31 F Liquid: 77 F
Chart Shows Refrigeration per lb. = 500 B.t.u. Refrigeration per 1000 lb. per day = 1.737 tons

Fig. 2-Refrigeration supplied by liquid ammonia

Fig. 3-Refrigeration supplied by calcium-chloride brine for any temp. rise


Directions:
Line from specific gravity on A through temperature difference (between inlet and outlet brine) on B cuts C on refrigerating effect in B.t.u. per lb. of brine. (Multiply brine flow, in millions of lb. per 24 hrs., by factor on right side of scale C to get tons of refrigeration delivered.)
Specific Gravity at 60 F.
A
1.3 1.2 1.1 1.0
30 20 10 0
Lb. CaCl2 per 100 Lb. of Brine
B
Temperature Rise, Deg. F.
100 70 50 40 30 20 10 7 5 4 3 2 1
C
70 60 50 40 30 20 16 14 12 10 8 7 6 5 4 3 2 1.6 1.4 1.2 1
200 160 140 120 100 80 70 60 50 40 30 20 16 14 12 10 8 7 6 5 4 3 2.5
Refrigeration, B.t.u. per Lb.
Refrigeration, Tons per 1,000,000 Lb. per 24 Hrs.
Problem & Solution
Brine of 1.24 specific gravity (at 60F) is made with 25 lb. CaCl2 to 100 lb. brine. If temperature difference is to deg. F., refrigeration delivered = 4.05 B.t.u. per lb. = 14 tons per million lb. brine per 24 hrs.

5. ELECTRICITY

THESE two pages will attempt to summarize those electrical definitions, laws, rules and data of most immediate concern in process applications, omitting electrical machinery.

Direct Current

"*I*" stands for *Amperes*, electrical current, corresponding to the rate of flow of water in a pipe

"*E*" stands for *Volts* (electromotive force), the electrical pressure which causes the current to flow

"*R*" stands for *Ohms*, resistance to flow, corresponding to the resistance a pipe offers to the flow of water

Ohm's Law, the most important in electrical engineering, may be written:

$$I = E \div R$$

Amperes = *Volts* divided by *Ohms*

$$I = E \div R$$

Amperes = Volts ÷ Ohms

$$E = I \times R$$

Volts = Amperes × Ohms

$$R = E \div I$$

Ohms = Volts ÷ Amperes

There will be no difficulty in applying Ohm's Law if the following rules are remembered:

1. Always think in terms of two points in the circuit. *I* is the current flowing *between these two points*. *E* is the voltage difference *between these two points*. *R* is the resistance *between these two points*.

2. Volts difference between two points is measured directly by connecting an instrument, known as a volt-meter, to them.

3. Amperes are measured by connecting an ammeter in series in the circuit.

4. Resistance between the two points is computed by Ohm's Law from measured volts and amperes, or measured by other electrical means, or computed from the length, diameter and material of the conductor.

Figs. 1, 2 and 3 show the three fundamental applications of Ohm's Law, wherein the unknowns are, respectively, amperes, ohms, volts.

Combined Resistances

Where several known resistances are combined, it is necessary to know the resistance of the combination before Ohm's Law can be applied. The rules (illustrated by Figs. 4 and 5) are simple: Resistances in series add up. Where resistances are in parallel their conductances add up. Conductance is the reciprocal of resistance.

Figs. 6 and 7 show how these rules, plus Ohm's Law, permit solution of a complex network of resistances in series and in parallel. Such a network should be worked from the "inside out" as far as possible. Thus the unit *BC* (Fig. 6) reduces to three resistances in parallel: 5 ohms, 5 ohms and 8 ohms. Their conductances add up and give a combined resistance of 1.905 ohms for *BC*. This is in series with the 2 ohms of *AB*, giving a resistance of 3.905 for the unit *AC*. Unit *AC*, in turn, is in parallel with the 4-ohm resistance of *DE*, and the two conductances again add up, giving a resistance of 1.976 ohms for the entire network *FG*. Fig. 6 summarizes these group resistances and shows the resistance and conductance of all the parts.

The principle illustrated in Fig. 7 follows directly from Ohm's Law. If, for example, there is 100 volts drop across the turns of a uniform coil 100 in. long, then there will be 32 volts drop across 32 in. of the coil, and 10 volts drop between points on the coil 10 in. apart.

Power and Energy

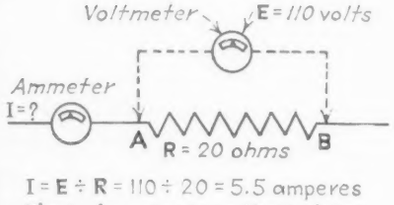
The watt is the basic electrical unit of power. One ampere (direct current) flowing under a pressure of one volt is one watt. For D.C., volts times amperes equals watts.

Watts may be measured indirectly by ammeter and voltmeter, or directly by wattmeter (see Fig. 15). Watts $= EI = RI^2 = E^2 \div R$. Thus, if $E = 100$ volts and $R = 5$ ohms, $I = 100 \div 5 = 20$ amp. Then watts $= EI = 100 \times 20 = 2{,}000$, or watts $= RI^2 = 5 \times 20 \times 20 = 2{,}000$, or watts $= E^2 \div R = 100 \times 100 \div 5 = 2{,}000$.

Note that horsepower, watts and kilowatts are not measures of energy, but of power, which is the *rate* of delivering energy. *Quantity* of energy, the thing you pay for on your power bill, is measured in watt-hours, kilowatt-hours, horsepower-hours.

The B.t.u. (see "Hot Water," page 644) is another unit of energy, as is the foot-pound of work. The relation of the common engineering units of power and energy are shown in the table. No energy is ever destroyed in a conversion, but much may go into undesired forms.

Problem: 4.3 kw. is consumed by a motor with an efficiency of 80%. How much mechanical power is produced and how much heat?



I = E ÷ R = 110 ÷ 20 = 5.5 amperes

Fig. 1 - Amperes = volts ÷ ohms

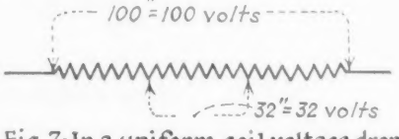
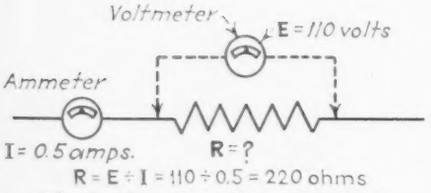
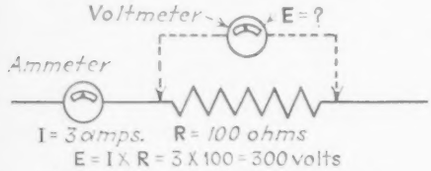


Fig. 7 - In a uniform coil voltage drop is proportional to distance



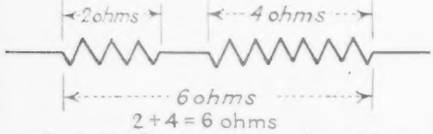
R = E ÷ I = 110 ÷ 0.5 = 220 ohms

Fig. 2 - Ohms = volts ÷ amperes



E = I X R = 3 X 100 = 300 volts

Fig. 3 - Volts = amperes x ohms



2 + 4 = 6 ohms

Fig. 4 - Resistances in series add up

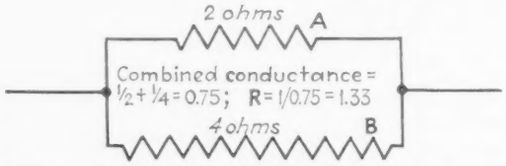
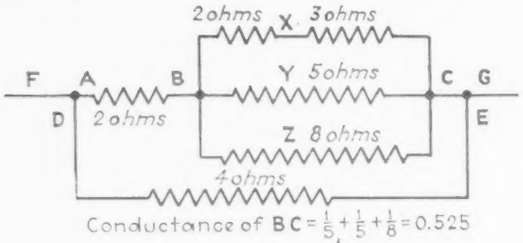


Fig. 5 - With parallel resistances conductances add up



Conductance of BC = $\frac{1}{5} + \frac{1}{5} + \frac{1}{8} = 0.525$

Resistance of BC = $\frac{1}{0.525} = 1.905$

Resistance of AC = 2 + 1.905 = 3.905

Conductance of FG = $\frac{1}{3.905} + \frac{1}{4} = 0.506$

Resistance of FG = $\frac{1}{0.506} = 1.976$ ohms

Fig. 6 - Figuring resistance of network of resistances in series and parallel

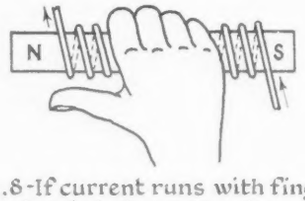


Fig. 8 - If current runs with fingers thumb points to north pole

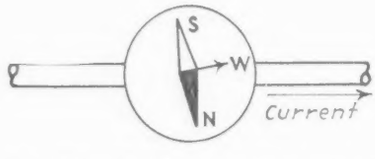


Fig. 9 - "West" side of needle, placed over conductor, points with D.C.

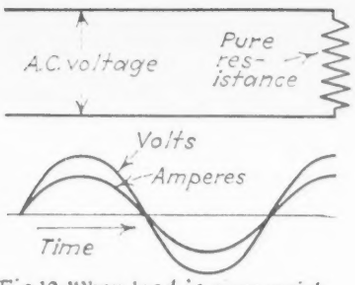


Fig.10-When load is pure resistance, volts and amperes are in phase", "power factor" is 100%

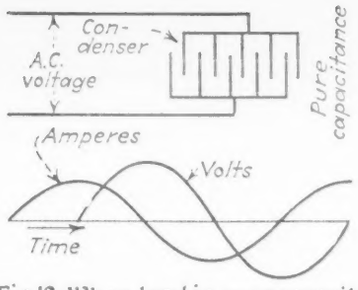


Fig.12-When load is pure capacity, amperes lead by 90 deg. Power factor is zero

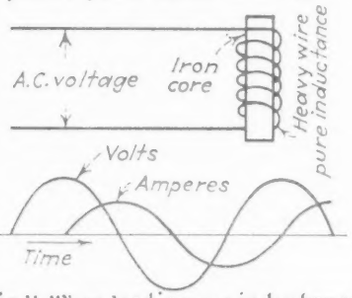


Fig.11-When load is pure inductance, amperes lag 90 deg. Power factor is zero

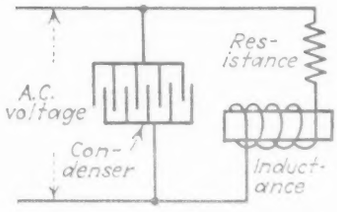


Fig.13-Added capacity brings power factor back to 100%

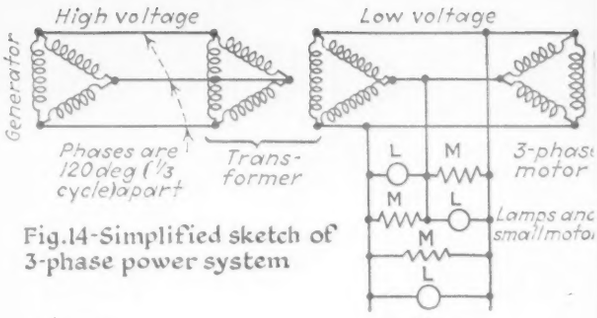


Fig.14-Simplified sketch of 3-phase power system

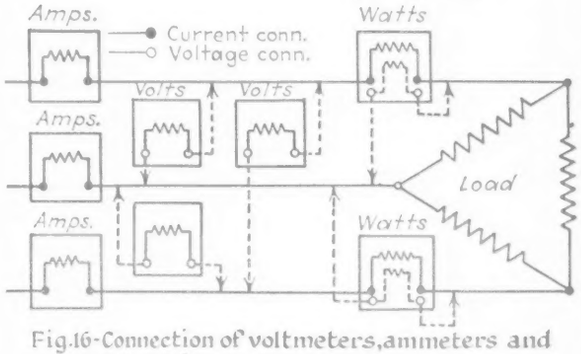


Fig.16-Connection of voltmeters, ammeters and wattmeters in 3-phase circuit

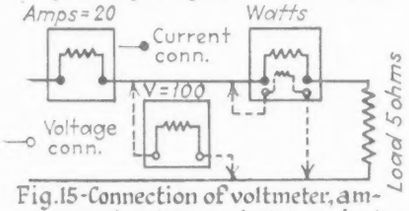


Fig.15-Connection of voltmeter, ammeter and wattmeter in D.C. or single-phase A.C. circuit

Solution: Electrical power to mechanical = 0.80 × 4.3 = 3.44 kw.

Mechanical power = 3.44 × 1.341 = 4.61 hp.

Electrical power to heat = 0.20 × 4.3 = 0.86 kw.

Heat produced = 0.86 × 3,412 = 2,934 B.t.u. per hr.

Magnetism

A tool-steel rod, hardened and magnetized, generally has one north pole and one south pole. Freely suspended, the north pole is the one that points north. Either pole will attract soft iron or steel. When two magnets are brought close opposite poles attract and like repel. Thus, to identify pole of a magnet, bring a pocket compass near it. North pole of magnet will attract south pole of compass.

Soft iron or steel becomes temporarily magnetic when surrounded by a coil of wire through which direct current is passing. Fig. 8 shows how to predict polarity.

Fig. 9 shows how compass will indicate direction of direct current in a conductor. Magnetizing effect of a coil is proportional to amperes multiplied by turns. Actual magnetic strength is limited also by the "permeability" of the iron or steel core, if any. As the core approaches saturation the magnetic strength does not pick up as fast as do the ampere turns. With alternating current, polarity alternates also.

Alternating Current

In the space available it is not possible to give an adequate outline of the principles of a.c. (alternating current), but a few high points will be mentioned. A.c. flows back and forth in the conductor like the swing of a pendulum. One complete swing back and forth is called a cycle. 60-cycle current has 60 complete double swings and 120 single swings (alternations) per second. The number of cycles per second is called the frequency.

In a.c. as in d.c., voltage is required to produce current. The push of the voltage may, or may not, be in time (in phase with) the current. When volts and amperes are exactly in phase all of the laws of direct current (such as Ohm's Law) apply to a.c., without change. This condition exists when the circuits contain resistances only, without magnetic efforts (inductance) or condenser effects (capacitance). It may also exist when inductance is balanced with capacity.

Fig. 10 shows a circuit with simple resistors, having no appreciable magnetic effect. This gives volts and amperes in phase. In this case watts equals volts times amperes, and the "power factor" is 1 (unity) or 100%. Power factor is the factor which, when multiplied by the product of volts and amperes, gives the watts (or, multiplied by kva., gives kw.).

Fig. 11 goes to the other extreme, showing a laminated core of soft steel wound with a few turns of heavy wire of practically "zero" resistance. This arrangement produces the effect known as "inductance," the electrical equivalent of inertia or flywheel effect. Here amperes lag practically one-quarter cycle (90 deg.) behind volts, the latter being at a maximum when the current is zero, and zero when the current is a maximum. In this case we have volts and amperes but no watts. No work is done, no real energy is consumed and the power factor is zero. Volts times amperes times zero power factor equal zero watts. The whole arrangement is equivalent to a frictionless pendulum swinging in a vacuum.

Another arrangement giving practically zero power factor is shown in Fig. 12. This circuit contains a condenser, but no resistance or inductance. In this case amperes are 90 deg. (¼ cycle) *ahead* of volts. As before, no energy is delivered and the power factor is zero. The condenser is the electrical equivalent of a spring.

"Power factor" is a very important practical matter because the so-called "wattless current" (that which is doing no work) overloads generators, transformers and conductors, and wastes energy as heat through resistance. Thus power contracts often penalize low power factor. The right combination of capacity and inductance, Fig. 13, will give 100% power factor.

Single-phase alternating current is handled by a simple two-wire circuit exactly like that used for direct current. Single-phase a.c., however, is not well suited for motor operation. Thus, a.c. is almost universally generated today as 3-phase. Transmission and much of distribution are also 3-phase. Fig. 14 shows 3-phase generation, transmission and distribution. Some of the application equipment is connected 3-phase. Lamps and very small motors use a single phase.

Ohm's Law applies to a.c. circuits if R is made to stand for "Impedance" rather than resistance. Measuring I and E for one set of conditions, the impedance equals $E \div I$.

Fig. 15 shows connections for measuring d.c. (or 1-phase a.c.) amperes, volts and watts. For a.c., watts ÷ (volts times amperes) = power factor.

Fig. 16 shows at left connections to measure amperes and volts in a 3-phase system, and at right, for measuring watts. Sum of two wattmeter readings gives total wattage of 3-phase circuit. If E represents average volts and I average amperes; Kva. of circuit = $1.732\,EI \div 1{,}000$.

POWER AND ENERGY CONVERSIONS

POWER

1 kw. = 1,000 watts = 1.3415 hp. = 2,656,000 ft.-lb. per hr. = 3,412 B.t.u. per hr.

1 hp. = 746 watts = 0.746 kw. = 550 ft.-lb. per sec. = 33,000 ft.-lb. per min. = 1,980,000 ft.-lb. per hr. = 2,543 B.t.u. per hr.

ENERGY

1 kw.-hr. = 1,000 watt-hours = 1.3415 hp.-hr. = 2,656,000 ft.-lb. = 3,412 B.t.u.

1 hp.-hr. = 746 watt-hours = 0.746 kw.-hr. = 1,980,000 ft.-lb. = 2,543 B.t.u.

1 B.t.u. = 778 ft.-lb.

6. COMPRESSED AIR

As a power service to process, compressed air is described in terms of its pressure, temperature, relative humidity (or suspended moisture if humidity is 100%), content of oil, dust and other impurities. Compressed air has innumerable uses; for example, operating air-driven hand tools, air presses, air clamping devices, air hoists and paint sprayers, agitating solutions, pumping water and solutions, (particularly corrosive chemicals), cleaning objects, etc.

While perfectly clean air, completely free from moisture, is not found in practice, its characteristics approximate closely those of ordinary air. Air at 60 F and 14.7 lb. abs. is often referred to as standard air. At this condition one cubic foot of dry air weighs 0.0764 lb. and one lb. occupies 13.10 cu. ft. In the following formulas, P is the absolute pressure, lb. per sq. in. (at sea level, it is gage pressure plus 14.7 lb.) and T is absolute Fahrenheit temperature (Fahrenheit temperature plus 460 degrees).

$$\text{Cu. ft. per lb.} \quad \frac{0.37T}{P}$$

For a given weight of air, the volume is proportion to the absolute temperature if the pressure is constant, and the volume is inversely proportional to the absolute pressure if the temperature is constant. Thus if air is heated from 400 F abs. to 800 F abs. (—60 F to 340 F) at constant pressure the volume will double.

Taking an atmosphere at 15 lb. approximately, 1 cu. ft. at 1 atm. abs. (zero gage), compressed to 5 atmospheres abs. (60 lb. gage) without temperature change will occupy 1/5 cu. ft. Fig. 3 gives for any pressure and temperature the equivalent cubic feet of air at the same temperature and at 14.7 lb. abs. Fig. 2 gives the weight of a cubic foot and the cubic ft. occupied by 1 lb. for any temperature (abs. or F) and any pressure (abs. or gage).

Atmospheric pressure varies slightly from day to day at a given altitude and lowers considerably as altitude increases. Altitude decreases the capacity of compressors and increases power required to compress air. It also affects air consumption of tools. Correction for these is important at high altitudes; plants so located should consult compressed-air handbooks for the necessary corrections.

Consumption of air-using equipment and capacity of compressors are usually given in terms of cubic feet of "free air." The term "free air" does not mean air at standard conditions of 60 F and 14.7 lb. pressure, but means air at the existing atmospheric condition at the compressor intake.

Fig. 1 shows the power requirements per 1,000 c.f.m. of free air for any final pressure from 30 to 200 lb. per sq. in. If the flow of compressed air to a process machine is known, the power required can be readily determined. Flow of air may be measured with nozzles or orifices and by the same type of meters used to measure steam flow discussed on page 665.

When air is distributed through long pipe lines, the loss in pressure may interfere with the proper operation of the connected equipment, hence air distribution pipe size should be carefully determined. The chart, Fig. 5 shows the magnitude of friction pressure loss in pipe.

MOISTURE CONTENT. One cubic foot of air at a given temperature contains a fixed amount of vapor at 100% humidity, regardless of pressure, Fig. 4. If atmospheric air at 60 F. is compressed to 15 lb. gage and allowed to cool at this pressure again to 60 F, its original relative humidity will be doubled (but not to exceed 100%). Multiplying the absolute pressure 5 times multiplies the humidity 5 times. Wherever this gives a figure above 100%, all of the excess must condense out somewhere in the system. This does not happen in the compressor, because the heating effect increases water capacity faster than reducing the volume destroys it. But air eventually cools to at least inside atmospheric temperature, either in the aftercooler or in the line to process. Thus air of 20% relative humidity at 60 F compressed to 60 lb. gage and cooled to 60 F becomes 100% humidity, 40% humid air compressed in the same way would dump half its moisture.

Obviously wet air is bad in process. As much of the water as possible should be removed immediately after compression. This can be done efficiently by passing the air through an "aftercooler." Sometimes, to dry it sufficiently, it becomes necessary to reheat the air at the process. This also gives greater volume.

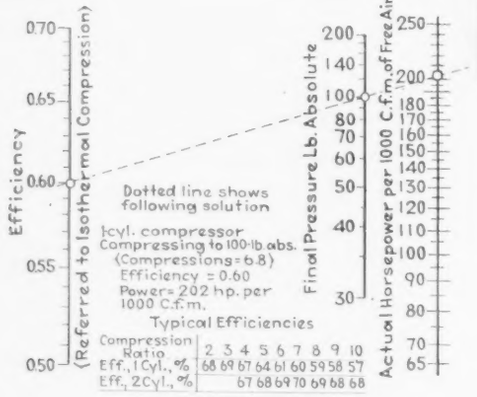

Efficiency
(Referred to Isothermal Compression)
Final Pressure Lb. Absolute
Actual Horsepower per 1000 C.f.m. of Free Air
Dotted line shows following solution
1cyl. compressor
Compressing to 100 lb. abs.
(Compressions = 6.8)
Efficiency = 0.60
Power = 202 hp. per 1000 C.f.m.
Typical Efficiencies
Compression Ratio 2 3 4 5 6 7 8 9 10
Eff., 1 Cyl., % 68 69 67 64 61 60 59 58 57
Eff., 2 Cyl., % 67 68 69 70 69 68 68

Fig. 1-Horsepower required to compress 1,000 c.f.m. of air from suction pressure of 14.7 lb. abs.

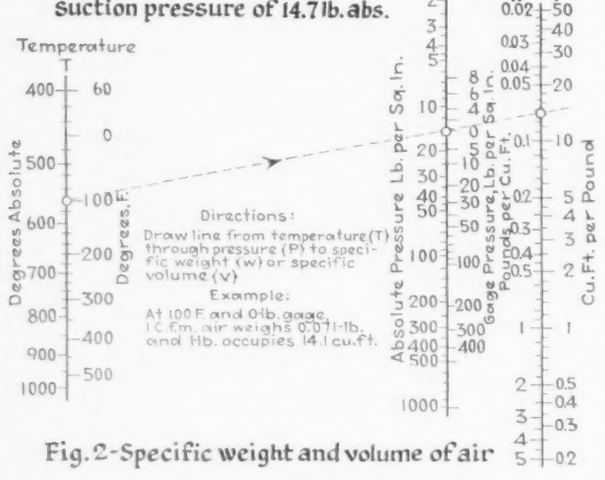

Temperature
Degrees Absolute
Degrees F.
Pressure P
Absolute Pressure Lb. per Sq. In.
Gage Pressure, Lb. per Sq. In.
Specific Wgt. Vol.
Pounds per Cu. Ft.
Cu. Ft. per Pound
Directions:
Draw line from temperature (T) through pressure (P) to specific weight (w) or specific volume (v)
Example:
At 100 F and 0 lb. gage 1 C.f.m. air weighs 0.071 lb. and 1 lb. occupies 14.1 cu. ft.

Fig. 2-Specific weight and volume of air

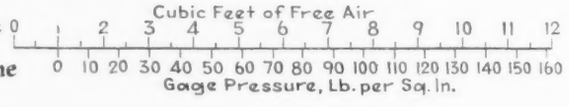


Fig. 3-Cubic feet of free air equal to 1 cu. ft. of compressed air at same temperature

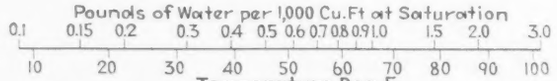
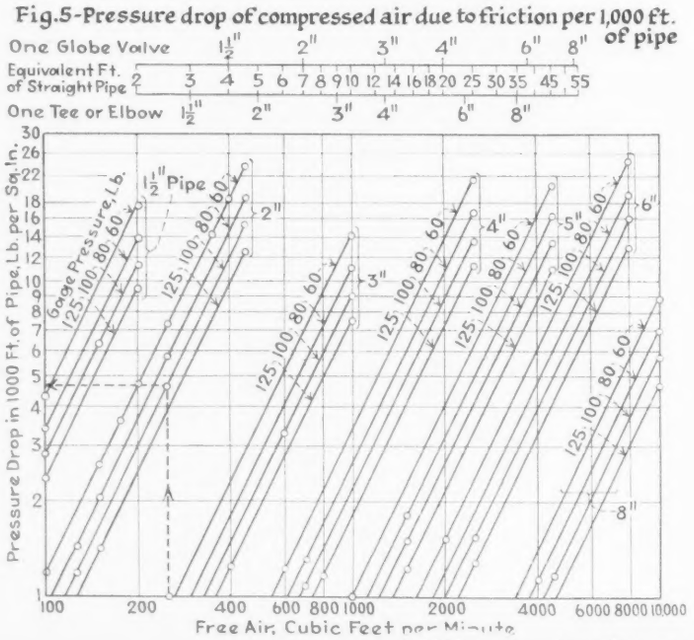


Fig. 4-Weight of water in 1,000 cu. ft. of saturated air

Fig. 5-Pressure drop of compressed air due to friction per 1,000 ft. of pipe


One Globe Valve
Equivalent Ft. of Straight Pipe
One Tee or Elbow
Pressure Drop in 1000 Ft. of Pipe, Lb. per Sq. In.
Gage Pressure, Lb.
125, 100, 80, 60
Free Air, Cubic Feet per Minute

7. CONTROLLED ATMOSPHERE

THE art of controlling air conditions has brought to the process industries a new tool for improving product quality, decreasing spoilage, and shortening manufacturing time. For these purposes the conditions maintained are generally selected to suit the product, but often air conditioning for comfort also decreases spoilage and man-hours of labor per unit of product.

"Air conditioning" involves the control of temperature, humidity, air motion and cleanliness. "Controlled atmosphere" may involve control of any or all of these factors and in addition control of the chemical composition, ion content and bacteria or mold content. To obtain this control it may be necessary to heat, cool, humidify or dehumidify, depending upon conditions required by the process. But in any case air motion must be created and controlled. It is just as important when the atmosphere is conditioned for the purpose of controlling a drying process, as when conditioning for comfort.

When conditioned air is furnished for purposes of comfort, care must be taken to avoid drafts and dead spots. But for process work frequently it is necessary to arrange air supply so the product is swept by the flow of conditioned air. Sometimes low humidity and slow air movement are required, whereas for other products high humidity and rapid air movement give best results. Application of this new tool to process control to obtain best results may require some research, but money so invested is usually well spent.

In drying processes, the product gives up moisture to the air and the air in turn must be dehumidified. Hence of primary interest is the humidity of the air, though temperature is also important. Relative humidity is a measure of the air's ability to absorb moisture. It is determined from wet- and dry-bulb thermometer readings and a psychrometric chart such as Fig. 2. From it may be determined the actual weight of water per pound of air and the relative humidity, which is really the per cent saturation.

At high temperatures drying can be done by continuously exhausting moisture-laden air from the room and replacing it with preheated outside air of lower moisture content. For example, assume a smoked-meat room maintained at 110 F. and 50% relative humidity, and outside air on a humid day with a dry-bulb temperature of 75 F. and a wet-bulb of 73 F. From the psychrometric chart, Fig. 2, the relative humidity of the outside air is found to be 90%. The question is how much air must be exhausted from the room and replaced by outside air to remove moisture at a required evaporation rate.

The chart of Fig. 1 can be used for this problem. Enter the chart at the inside dry-bulb temperature, and at the intersection of the inside relative humidity move horizontally to the right to the blank scale *A*. From this intersection draw a line to the zero value on moisture scale *C*. Enter the chart again with the outside dry-bulb temperature, rise vertically to the outside relative humidity and then horizontally to the *A* line. From this intersection draw a line through the intersection of the indoor line with the blank scale *B*, and the intersection with scale *C* (at 0.066 in the example shown) gives the net pounds of moisture removed per 100 cu.ft. of air exhausted and replaced by fresh outside air.

If, however, drying is to be carried out at a low temperature, say 55 F. and 70% relative humidity, it is obvious that outside air cannot be used, as its moisture content is greater than that of the inside air. In this case the air supplied to the room must be dehumidified. If this is done by passing air through a spray of cold water at, say, 40 F. the relative humidity of the air supply when heated to room temperature will be 55%. If this value is used in the chart, Fig. 1, it will be found that the moisture removed per 100 cu. ft. is quite small. If the amount of moisture to be removed were the same as in the previous examples, about 6 times as much air must be circulated.

In many cases the direct opposite of drying is required, and air conditions must be controlled to prevent evaporation of moisture from the product. To do this, the room conditions must be kept at high relative humidity and air supplied has to be humidified instead of dehumidified. In such instances the problem of preventing condensation on cool surfaces may become acute.

A system of air conditioning must be more than an assembly of equipment that will heat, cool, humidify or dehumidify. These units must operate together to form an integrated system, and this largely depends upon the controls provided and methods of operation.

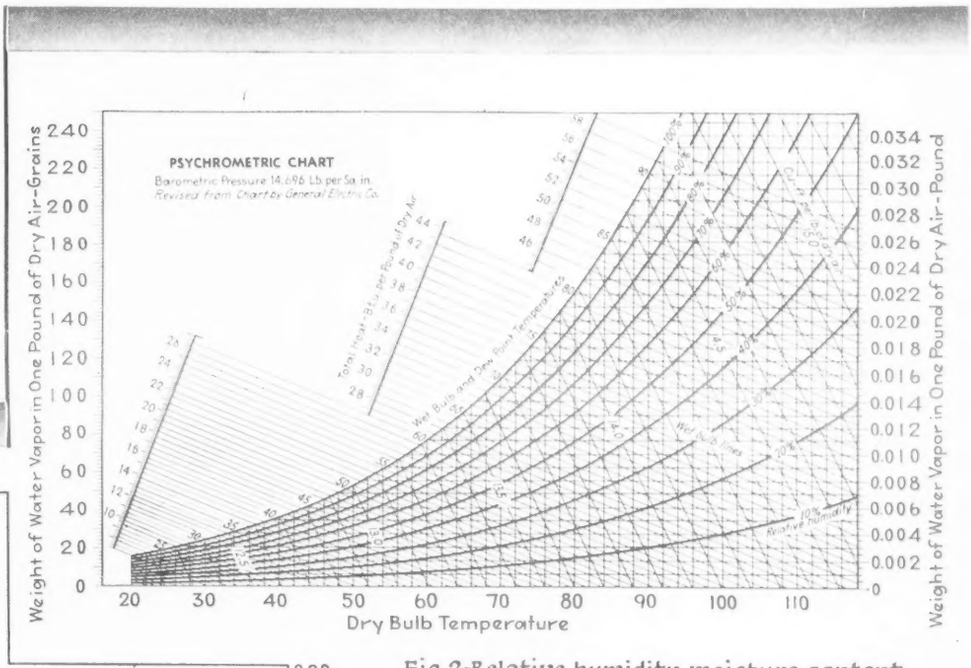

PSYCHROMETRIC CHART
Barometric Pressure 14.696 Lb. per Sq. in.
Revised from Chart by General Electric Co.
Weight of Water Vapor in One Pound of Dry Air—Grains
Weight of Water Vapor in One Pound of Dry Air—Pound
Dry Bulb Temperature
Total Heat—B.t.u. per Pound of Dry Air
Wet Bulb and Dew Point Temperatures—F.
Relative Humidity

Fig. 2-Relative humidity, moisture content, and total heat per pound of air found from this chart

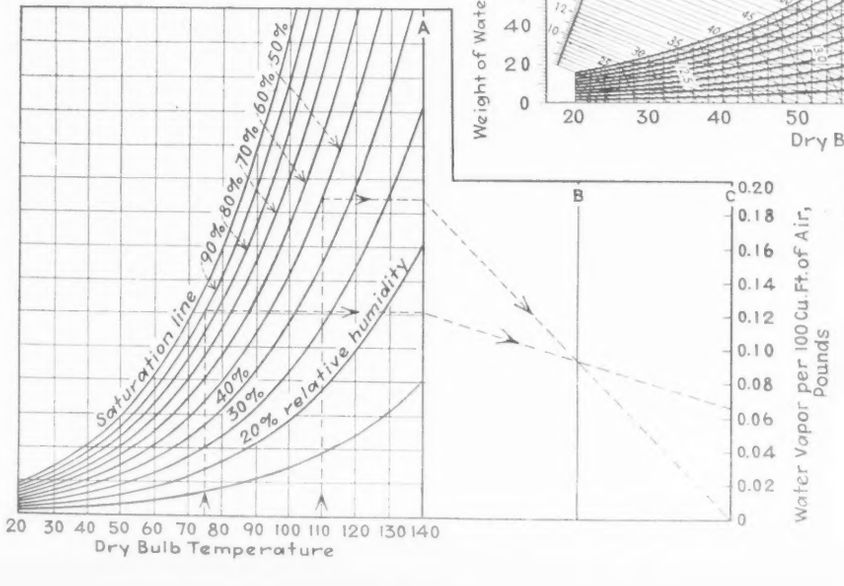


Fig. 1-Chart for finding moisture removed by exhaust air

8. MECHANICAL POWER

"MECHANICAL POWER" here means primarily power delivered by the movement of solid bodies: Shafts, pulleys, belts, gears, chains, sprockets, levers, cams, etc.

This "Basic Services" section deals with the services after generation. Therefore mechanical power transmission would logically fall in here. Since, however, all practical angles of this subject cannot possibly be summarized in one page, and since a 16-page section (Feb., 1936, *Power*) has already been devoted to them, it seems best here to give basic principles.

This article, then, is an attempt to compress the most important mechanical laws governing solids into a single page for quick and convenient reference.

Each of the 15 sketches illustrates a law and solves a numerical problem. Each caption states the law as a formula. All symbols in these formulas are defined in the accompanying table.

Special attention should, however, be called to the following practical application of several of the laws:

Fig. 3. Gives the work developed or absorbed when a weight falls or rises, or a piston moves under pressure.

Fig. 4. Gives the speed of a hammer dropped from any height. Gives the blow, in foot-pounds, struck by any moving mass.

Fig. 6. Gives the side thrust in a fixed-bearing centrifuge unevenly loaded.

Fig. 7 Gives the approximate "flywheel effect" of the typical flywheel.

Fig. 8. Permits figuring the energy of blow delivered by a flywheel press with a given r.p.m. drop.

Fig. 9. Shows how to figure concurrent forces at end of a jib crane or at any other junction of structural members.

Fig. 10. Gives horsepower from prony brake test data. Gives torque required to deliver any horsepower at any r.p.m.

Fig. 11. With this law, one can figure any problem in leverages.

Fig. 12. Enough to figure the "mechanical advantage" (gain in force or torque) from any conceivable combination of levers, gears, pulleys, cams, etc., if the relative speed of the input and output members of the unit can be measured or figured.

Fig. 13. Widely used in problems of balancing and the leverage of weights.

Fig. 14. A convenient plant kink with many uses.

Alphabetical Key to Symbols

A=Acceleration, ft. per sec. per sec.
C=Centrifugal force, pounds
D=Distance moved, feet
E=Energy in foot-pounds (Note: kinetic energy equals work required to produce it)
F=Force, pounds
g=32.2=Acceleration of gravity
HP.=Horsepower
M=Mass, lb. (Equals weight, W)
m=Moment of inertia of rotating body (Also called "Flywheel Effect")
N=R.P.M.
P=HP=Horsepower
R=Radius of a wheel, or lever arm of a force or mass, feet
r=Radius used in figuring m, feet
$R.P.M.$=Revolutions per minute (Note: Also called N)
T=Time, seconds
t=Torque, or turning movement, pound-feet
V=Velocity, feet per second
W=Weight, pounds (Equals mass, M)
w=Work done, foot pounds (Note: Equals energy, E, produced by, or producing, the work)

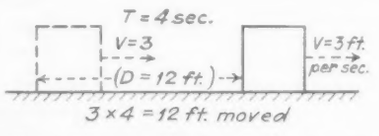


Fig.1-For constant velocity, D=VT

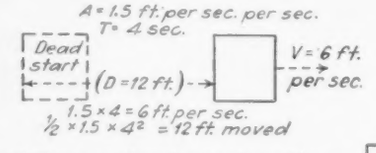


Fig.2-For constant acceleration and a dead start,
$V = AT$ $D = \frac{1}{2} AT^2$

Fig.3-(Left) $w = FD$ also $w = WD$

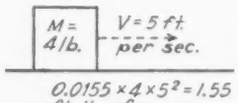


Fig.4-$E = 0.0155\ MV^2$ = work to stop or start

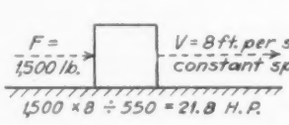


Fig.5-$P = FV \div 550$

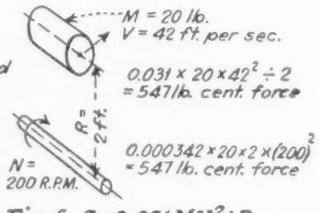


Fig.6-$C = 0.031\ MV^2 \div R$
$C = 0.000342\ MRN^2$

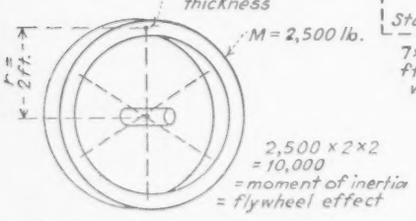


Fig.7-m for thin rim = Mr^2

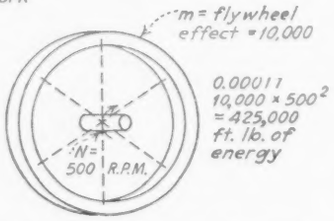
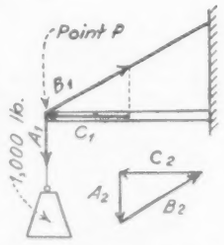
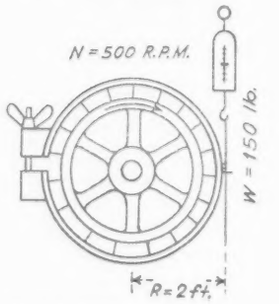


Fig.8-$E = 0.00017\ mN^2$ = work to start or stop



A_1 (known) is 1,000 lb. Draw A_2 parallel and equal to A_1. Draw B_2 and C_2 parallel to B_1 and C_1. Scale B_2 = 2,100 lb. = B_1 C_2 = 1,900 lb. = C_1

Fig.9-Forces balanced at a point complete a triangle or polygon



2 × 150 = 300 ft. lb. torque
0.00019 × 300 × 500 = 28.5 H.P. developed

Fig.10-$t = RF$
$P = 0.00019\ tN$

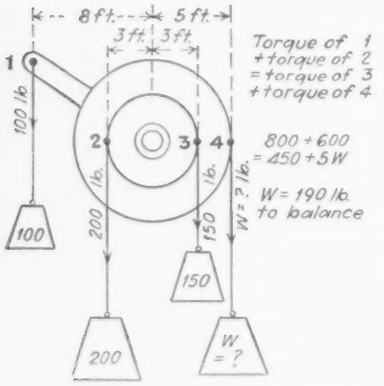


Fig.11-For balance sum of left-hand torques = sum of right-hand torques

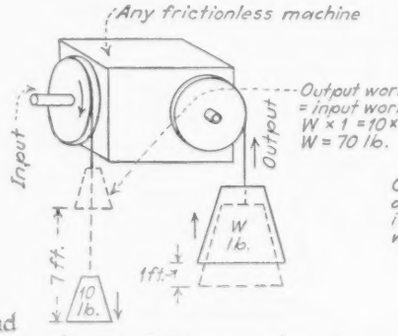


Fig.12-Output work = input work

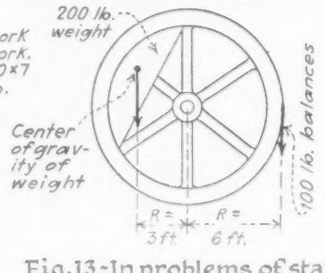


Fig.13-In problems of static balance, body acts as if weight were at center of gravity

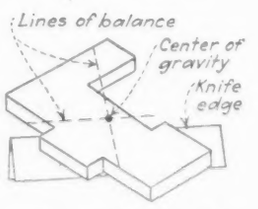


Fig.14-To find center of gravity of flat shape, balance shape on knife-edge two ways

1. HEAT TRANSFER

THE average power engineer can rarely find time to study the mathematical refinements of heat-transfer calculation. He can, however, easily master the theory of the flow of heat through solids, learn how to compute insulation losses and gain some facility in using the "over-all" heat-transfer coefficients of jacketed kettles, steam-heated rolls and similar common process equipment.

HEAT-FLOW LAW FOR SOLIDS

The heat-flow law for solids is an exact parallel of Ohms law for electricity: *flow equals potential difference divided by resistance.* In the best modern practice, the so-called *specific conductivity* of a solid is based on a 1-ft. cube (Fig. 1). Heat flows straight through from the hot face to an opposite face 1 deg. F. cooler. The *specific conductivity, R, is the heat, in B.t.u., flowing through this cube in one hour.* Sometimes (particularly with insulating materials) the conductivity is defined in terms of a 1-sq.ft. slab 1 in. thick. Conductivity based on 1-in. thickness is twelve times as great as the one here used.

For copper, R is 224. With 1-deg. temperature difference, 224 B.t.u. will flow through the cube of Fig. 1. Resistance of the cube (reciprocal of conductivity) is $1 \div 224 = 0.00446$. The electrical analogy is perfect. One volt will deliver 224 amperes through a resistance of 0.00446 ohms or a conductivity of 224.

Fig. 2 shows another electrical analogy. For a steady flow of heat through a wall of any uniform solid material, the temperature gradient (line of fall) is a straight line. Voltage along a uniform electrical resistance also falls in a straight line in exactly the same way (see pages 648-649).

Lower electrical conductivity per ft. (higher resistance per ft.) gives a steeper line of voltage drop for a given current flow. Lower specific thermal conductivity (higher specific resistance) gives a steeper temperature gradient for a given flow of heat.

Fig. 3 illustrates the method of applying heat-transfer coefficient. Heat transfer, in B.t.u. per hour, is simply $K \times$ area in square feet $\times$ temperature difference between faces, divided by thickness in feet. If coefficient used is based on 1-in. thickness, measure the wall thickness in inches instead of feet.

One bit of theory, very important in practical applications, is illustrated by Fig. 4. The plates of copper and cast iron are metallically bonded. Resistance of the copper block is 0.00089 and of the iron block 0.01. The two add up to 0.01089, only 9% more than the iron block alone. Heat flow is equal to the over-all temperature difference divided by the combined resistance. Only about 8% of the total temperature drop is in the copper.

Where a thickness of insulating material is placed outside a metal plate (Fig. 5) the metal generally takes far less than 1% of the total heat drop. Therefore, when dealing with heat transfer through insulated metal plates or tubes (regardless of kind or thickness of metal, within reason) assume the entire thickness of the metal to be at the temperature of the steam or liquid on the wet side.

FLUID TO FLUID THROUGH METAL

When heat is transmitted from gas through metal to water, the highest resistance is from gas to metal. Next highest is from metal to water and lowest is through the metal. For most process problems, the drop through the metal can be neglected if there is liquid or steam on one or both sides.

With water heating water, and the flow similar on both sides of the metal, the metal will take a temperature about halfway between the two water temperatures. With steam heating water, the metal will be close to the steam temperature. With steam or hot water heating still air, the temperature of the metal will be close to that of the steam or water. Always measure metal surface on the side of largest temperature drop.

Of greatest interest to *Power* readers serving processes is the case where saturated steam, in a jacket or coil, is used to heat or evaporate water or other liquid. For a given kettle, or other piece of heat-transfer equipment, total heat transfer will be about in proportion to the difference in temperature between steam and water. Fig. 3 on page 645 gives saturated steam temperatures for all pressures. Even where superheated steam is admitted, the superheat is soon lost, so that the saturation temperature controls. The *over-all heat-transfer coefficient U* is then merely the B.t.u. transmitted per hour per sq.ft. of heating surface per deg. difference in temperature between the liquid heated and the saturated steam.

Fig.3-B.t.u. per hr. = K x sq.ft. x temp diff.

Fig.4-Higher resistance of two in series practically controls heat flow

Fig.5-Less than 1% of total temp. drop occurs in total

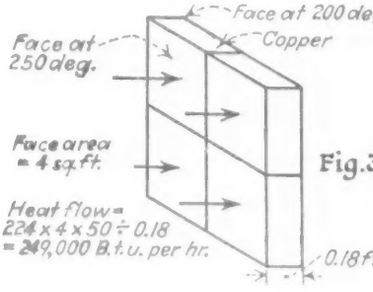


Fig.3

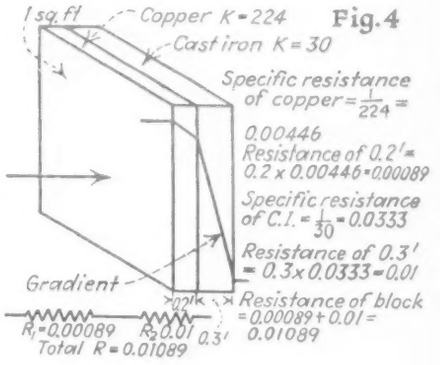

1 sq.ft.
Copper K = 224
Cast iron K = 30
Specific resistance of copper = 1/224 = 0.00446
Resistance of 0.2' = 0.2 x 0.00446 = 0.00089
Specific resistance of C.I. = 1/30 = 0.0333
Resistance of 0.3' = 0.3 x 0.0333 = 0.01
Gradient
0.2'
0.3'
Resistance of block = 0.00089 + 0.01 = 0.01089
R1 = 0.00089
R2 = 0.01
Total R = 0.01089

Fig.4

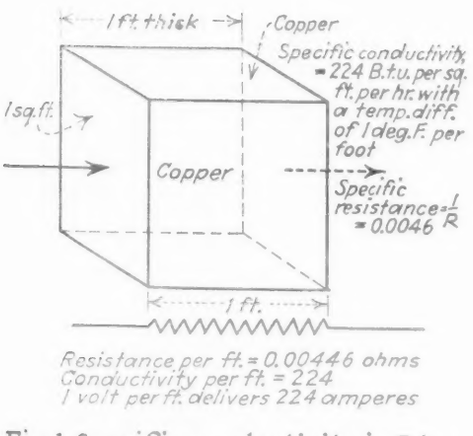

1 ft. thick
Copper
Specific conductivity = 224 B.t.u. per sq. ft. per hr. with a temp. diff. of 1 deg. F. per foot
1 sq.ft.
Copper
Specific resistance = 1/R = 0.0046
1 ft.
Resistance per ft. = 0.00446 ohms
Conductivity per ft. = 224
1 volt per ft. delivers 224 amperes

Fig.1-Specific conductivity is B.t.u. per hr. between faces of 1-ft. cube with 1-deg. F. temp. diff.

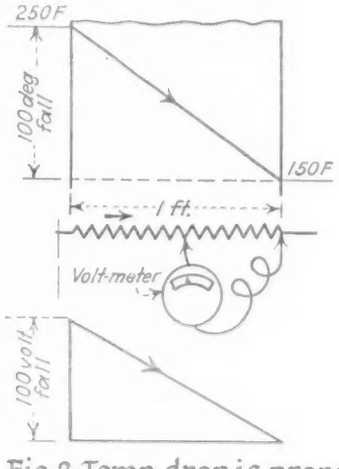


Fig.2-Temp. drop is proportional to heat flow and to resistance between the two sections

Fig.5

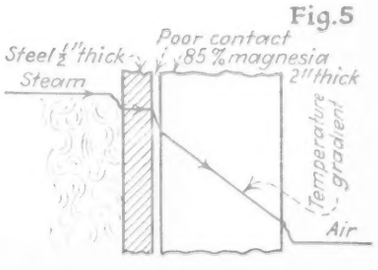


Fig.7-Chart for heat flow through tube or coil heater →

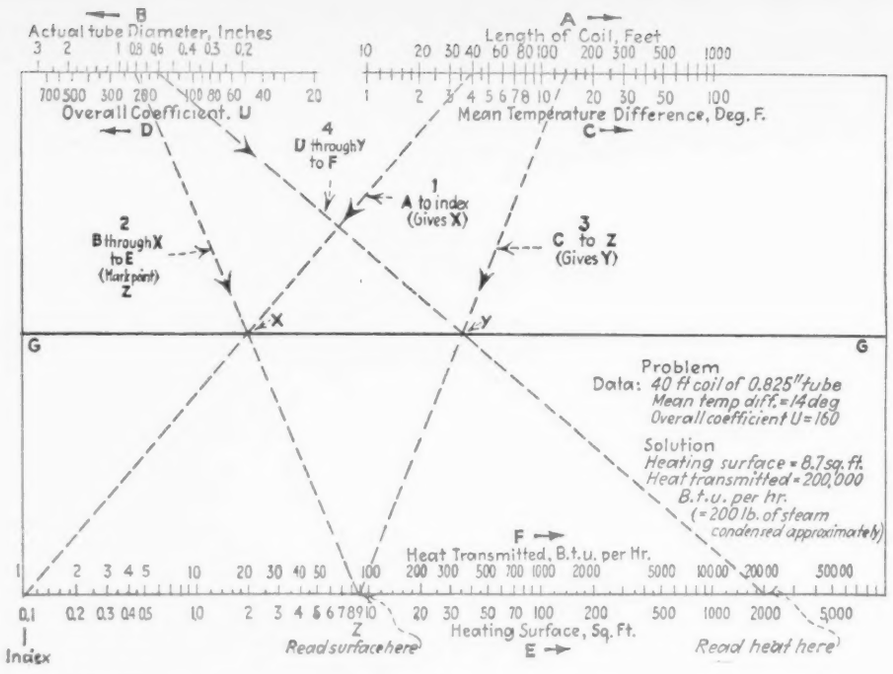
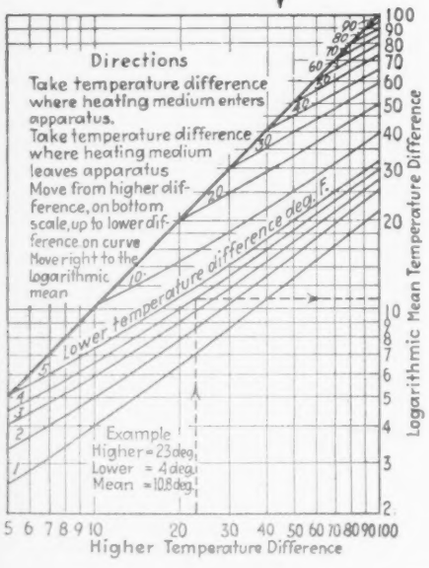

B
Actual tube Diameter, Inches
3 2 1 0.8 0.6 0.4 0.3 0.2
A
Length of Coil, Feet
10 20 30 40 60 80 100 200 300 500 1000
700 500 300 200 100 80 60 40 20
Overall Coefficient, U
1 2 3 4 5 6 7 8 10 20 30 50 100
Mean Temperature Difference, Deg. F.
D
C
4
D through Y to F
1
A to index (Gives X)
2
B through X to E (Mark point) Z
3
C to Z (Gives Y)
X
Y
G
G
Problem
Data: 40 ft coil of 0.825" tube
Mean temp. diff. = 14 deg
Overall coefficient U = 160
Solution
Heating surface = 8.7 sq. ft.
Heat transmitted = 200,000 B.t.u. per hr.
(= 200 lb. of steam condensed approximately)
F
Heat Transmitted, B.t.u. per Hr.
1 2 3 4 5 10 20 30 40 50 100 200 300 500 700 1000 2000 5000 10000 20000 50000
0.1 0.2 0.3 0.4 0.5 1.0 2 3 4 5 6 7 8 9 10 20 30 50 70 100 200 500 1000 2000 5000
Index
Z
Read surface here
Heating Surface, Sq. Ft.
E
Read heat here

Fig.6-Chart for logarithmic mean temp. diff. ↓


Directions
Take temperature difference where heating medium enters apparatus.
Take temperature difference where heating medium leaves apparatus
Move from higher difference, on bottom scale, up to lower difference on curve
Move right to the logarithmic mean
Lower temperature difference deg. F.
Example
Higher = 23 deg.
Lower = 4 deg.
Mean = 10.8 deg.
Logarithmic Mean Temperature Difference
100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2
5 6 7 8 9 10 20 30 40 50 60 70 80 90 100
Higher Temperature Difference

PRACTICAL PROBLEMS

The coefficient U is found by measuring the heat flow under one set of conditions and dividing this by the existing temperature difference and the heating surface.

Problem: An evaporator transmits 1,000,000 B.t.u. per hr. when the saturated steam at 250 F. heats liquid at 200 F. Surface is 100 sq.ft. What is U, and what would be the heat transfer with steam at 240 F. and liquid at 210 F.?

$1{,}000{,}000 = U \times 100 \times 50$; $U = 200$

With liquid at 210 and steam at 240, temperature difference is reduced to 30 deg. and heat transfer becomes:

$200 \times 100 \times 30 = 600{,}000$ B.t.u.

Table I gives values of U ranging from 50 to 800 for transfer from steam to water, and shows similar wide variations for other combinations. It should be emphasized that over-all coefficients from such tables are merely aids to preliminary guessing. Reliable coefficients can be developed only from experience with apparatus and conditions similar to those for which the coefficients are to be used.

When steam (in a jacket or submerged coil) heats boiling water or other boiling liquid, the mean temperature difference is merely steam temperature minus liquid temperature. Where steam heats a liquid in a tube, or one liquid heats another in a coil or tubular heat exchanger (either counter-flow or parallel-flow) temperature difference at exit differs from temperature difference at entrance. For rough work the two differences may be averaged to get the mean temperature difference to use in the formula. For greater accuracy use the *logarithmic mean temperature difference* (Fig. 6).

Fig. 7 is designed to save time in figuring heat transfer with coil or tubular heaters. The solution in dotted lines shows that a 40-ft. coil of 0.825-in. tube, with a mean temperature difference of 14 deg. and U of 160, will deliver 20,000 B.t.u. per hr. If the coil contains steam, this is equivalent to about 20 lb. per hr., since condensing steam gives up about 1,000 B.t.u. per lb.

The total heat transmitted in warming up a given weight of liquid (without boiling) is: *Heat = Weight × Temperature rise × Specific heat*

Specific heat of water is unity. This may also be used as the specific heat of any liquid largely water (e.g. soup and dilute water solutions of all kinds).

If a fluid of 0.67 specific heat is being warmed from 60 to 200 F. in the problem just figured (20,000 B.t.u. per hr. transmission) each pound will absorb $140 \times 0.67 = 94$ B.t.u. Weight heated per hr. will be $20{,}000 \div 94 = 213$ lb. When a liquid is heated the final temperature difference is less than the initial. Use the straight average difference or the logarithmic mean.

In boiling or preheating figure that the latent heat must be added to each pound evaporated. For water or water mixtures get the latent heat from steam tables for the given temperature, or use the round number 1,000 B.t.u. per lb.

In practice, heat is always lost from heat-transfer equipment to the surrounding air by radiation, convection and conduction. The loss to still air per square foot of exposed metal surface per deg. temperature difference between air and metal is given in Table II for both bare metal and that covered with a single standard thickness of 85% magnesia or equivalent material.

The methods shown in this article for figuring heat transfer in general and, in particular, for the heating and cooling of fluids by steam, apply also to cooling processes.

Table I

Range of Miscellaneous Over-all Coefficients

(Heat transfer in B.t.u. per hr. per sq. ft. of surface per deg. diff. in temp. between two fluids. From a tabulation by A. P. Colburn in Perry's *Chemical Engineer's Handbook*, McGraw-Hill Book Co.)

Type of heat exchanger	Controlling resistance		Typical fluid	Typical apparatus
	U free convection	U forced convection		
Liquid to liquid	25–60	150–300	Water	Liquid-to-liquid heat exchangers
Liquid to liquid	5–10	20–50	Oil	
Liquid to gas (atm. pressure)	1–3	2–10		Hot-water radiators
Liquid to boiling liquid	20–60	50–150	Water	Brine coolers
Liquid to boiling liquid	5–20	25–60	Oil	
Gas (atm. pressure) to liquid	1–3	2–10		Air coolers, ecomomizers
Gas (atm. pressure) to gas	0 6–2	2–6		Steam superheaters
Gas (atm. pressure) to boiling liquid	1–3	2–10		Steam boilers
Condensing vapor to liquid	50–200	150–800	Steam-water	Liquid heaters and condensers
Condensing vapor to liquid	10–30	20–60	Steam-oil	
Condensing vapor to liquid	40–80	60–150	Organic-vapor-water	
Condensing vapor to liquid		15–300	Steam-gas mixture	
Condensing vapor to gas (atm. pres.)	1–2	2–10		Steam pipes in air. Air heaters
Condensing vapor to boiling liquid	40–100			Scale-forming evaporators
Condensing vapor to boiling liquid	300–800		Steam-water	
Condensing vapor to boiling liquid	50–150		Steam-oil	

Table II

Heat Loss from Metal

(B.t.u. loss per hr. = Factor x temp. diff. x sq. ft. Measured temp. difference is that between liquid or steam and outside air. Insulated surfaces covered with single standard thickness of 85% magnesia or equivalent material)

Temp. diff. deg. F.		100	200	300	400	500
Factor	bare	2.1	2.7	3.3	4.0	5.2
	insulated	0.38	0 40	0 41	0.43	0.45

2. UNIT OPERATIONS

THE importance of a name is often underestimated. A name may stand for a great idea and may direct attention of thousands toward that idea. If the idea is good, the gain will be great. Process engineers have such a name for one of the most fertile concepts in the whole field of engineering. The name is "unit operation". The concept behind this name is that any process, whether it be paint manufacture, canning peas, or making paper, can be broken down into a series of simple steps or operations and that most of these will be found in all other process industries.

If every operation in every industry were different from all other operations in all other industries, there could be no such person as a process engineer in the general sense. We would have only paper engineers, sugar engineers, etc., and they would have nothing in common. On the contrary, they have so much in common that a real expert in one process has automatically mastered the fundamentals of most others. This is true because mastery of a process is largely mastery of its unit operations. This knowledge can be applied directly to the same unit operations in any other industry after gaining some familiarity with the specialized requirements of the particular product.

The elementary diagrams on this page and the next summarize most of the widely used unit operations. Almost every *Power* reader has encountered many of them, although terminology may be unfamiliar in some cases. These diagrams are simple in the extreme and drive home the point that the majority of process steps are obvious applications of every-day operations known to everybody long before this machine age. For example, millions of dollars are invested in equipment for mixing, yet any farmer equipped with a stick and a pail can do a fair job of mixing.

At least 21 of the 29 listed operations may be found in the household kitchen, as follows: moving solids, moving liquids, moving gases (fan), heat exchange gas-to-liquid (gas stove), heat exchange gas-to-solid (oven), evaporation, drying, crushing, grinding, mixing liquids, mixing solids, mixing solids with liquids, mixing plastics with plastics, plastics with liquids, and plastics with solids, mixing gas with gas (in gas burner), mechanical separation, filtering, washing, leaching, electric heating. This coincidence is of more than academic interest. Since most engineers are familiar with kitchen operations, it gives them a starting point for process studies.

All of the basic operations can be performed with extremely simple equipment. For example, you can leach wood ash for potassium compounds by letting water trickle through the ash in a barrel.

The numerous gadgets and frills which sometimes conceal the essential simplicity of process equipment have their reason, however. Percentage wastes which are perfectly justifiable in miniature operations become economic crimes when applied to operations consuming many thousands of dollars yearly in power services only.

It is a simple matter to heat, evaporate, mix and so on, whether the scale of operation be large or small, but to do so efficiently and with a high degree of control requires much technical knowledge. This is particularly true of the various operations involving heat transfer, which explains why a special article was devoted to that subject. The transportation of solids, liquids and gases is another difficult field if efficiency is required. Fortunately much of the power engineer's knowledge of the fluid-power services is applicable to the handling of process liquids and gases with little change except to provide against corrosion.

For convenience we shall group the unit operations to be discussed here under ten headings as follows:

1—Transporting
- A—Solids
- B—Liquids
- C—Gases

2—Heat transfer
- A—Heating and cooling
- B—Cooking and baking
- C—Evaporating

3—Drying and moisture control
- A—Drying solids
- B—Drying gases
- C—Controlled atmosphere

4—Size reduction
- A—Crushing
- B—Grinding

5—Mixing
- A—Solids
- B—Liquids
- C—Gases
- D—Combinations of these

6—Mechanical separation
- A—Screening
- B—Raking
- C—Inertia separation (cyclone or baffle)

7—Filtering
- A—Stationary filtering
- B—Rotary filtering
- C—Centrifuging

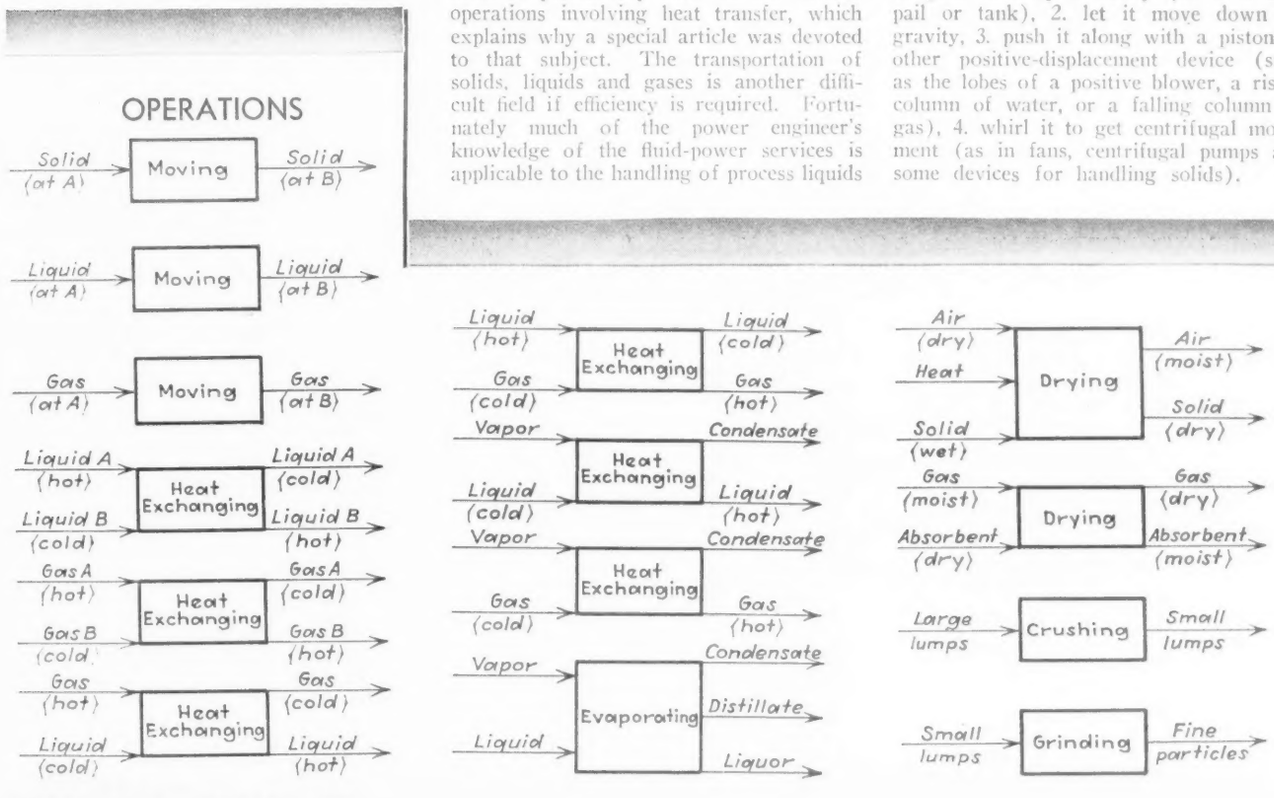
8—Washing and leaching

9—Gas scrubbing
- A—Absorbing
- B—Dust removal

10—Electrical
- A—Heating
- B—Electrolysis
- C—Combined heating and electrolysis

In discussing these operations briefly, we shall say as little as possible about the equipment used, since that will be discussed at length in the next article. The intention here is to concentrate on the basic principles of the unit operations.

Transporting—Fundamentally there are at least four ways to move a solid, liquid or gas: 1. carry it bodily (as in a box, pail or tank), 2. let it move down by gravity, 3. push it along with a piston or other positive-displacement device (such as the lobes of a positive blower, a rising column of water, or a falling column of gas), 4. whirl it to get centrifugal movement (as in fans, centrifugal pumps and some devices for handling solids).



HEAT TRANSFER Heat transfer is always from the hotter body to the colder. It occurs by conduction, radiation and convection. In most process equipment, the radiation transfer is not important on the side of the metal in contact with a liquid or a condensing vapor, such as steam. Radiation from the fire and brickwork is very important on the side of the metal exposed to it, but much less important on the air side of steam-heated radiator coils. Radiation goes up very rapidly as red heat is approached. For the majority of processes where no fire is involved it is much less important than conduction and convection.

Water and other liquids are very poor heat conductors, yet they carry heat away rapidly from the walls of kettles and heat exchangers because the heating sets up convection currents. High viscosity greatly reduces these currents and interferes seriously with heat transfer unless the liquid is stirred or otherwise agitated.

In liquid-to-gas heat transfer (or the reverse) heat flow is greatly speeded up if the gas passes rapidly over the metal. The explanation is "scrubbing action." In liquid-to-liquid exchangers, scrubbing on both sides is helpful.

A basic principle applicable to all kinds of heat exchangers is that where one side has much higher resistance than the other, scrubbing is of value only on the high-resistance side. Thus increased speed of saturated steam through a pipe does not appreciably increase the transfer of heat to the surrounding still air.

The distinction between evaporating and cooking has been explained in the article on heat transfer.

DRYING AND MOISTURE CONTROL Even without air movement, high enough temperature will rapidly remove moisture from a solid. It may also produce undesired changes. To dry rapidly at moderate temperatures, warm dry air must be forced over the solid. Direct heat may also be applied at the same time. Still dry air will dry as well if a much longer time is allowed. The important factor in drying by air is not so much its "relative humidity" as its capacity to pick up moisture. For the same relative humidity, this increases rapidly as temperature is increased.

Gases cannot be dried by heat. Moisture must be removed by absorption (by calcium chloride, silica gel, concentrated sulphuric acid, etc.) or by condensation. Moisture is condensed out when the gas is cooled below the dewpoint. By control of the refrigerating temperature, any desired actual moisture content may be attained.

Air may be used, not to dry, but to moisten or to prevent evaporation of moisture from such a product as tobacco or rayon. By controlling temperature and humidity of air in work rooms and store rooms, any desired moisture of the product can be maintained.

SIZE REDUCTION Sizes of solids are reduced first by the preliminary breaking-down process called "crushing," typified by the ordinary rock crusher. Further reduction is by grinding. Grinders operating by impact, rolling, attrition, etc., will reduce size until particles will go through 400- or 500-mesh if necessary. Horsepower hours per ton of product are theoretically in proportion to the new surface produced by grinding. According to this, half the particle diameter will require double the horsepower hours.

MIXING Mixing, in general, is a branch of conveying or transportation. A crowd mixes by walking around. To get a good mix it is necessary to avoid points of attraction for special groups. If everybody considers one spot as good as another, and the crowd keeps moving, the mixing will be thorough.

But pigment in paint seeks the bottom of the container and must be enticed away. Sand tends to slide downward between pebbles. Dust in a whirling current of air tends to fly out rather than mix. Mixing devices have been designed mainly by instinct and experience, rather than by scientific theory, but those that are effective allow for these conditions and many others. A paddle stirrer effective for mixing salt with water might be useless for mixing a batch of dough. Any mechanic can sense why. Most mixers operate by picking out portions of the mass at random and putting them somewhere else in the mass just as one could eventually shuffle a deck of cards by picking out one card at a time at random and sticking it somewhere else in the pack.

MECHANICAL SEPARATION Separation is the opposite of mixing. If the two substances mixed are alike in all properties that count they cannot be separated. However, big particles can be separated from small by raking or screening. Centrifugal action (cyclone) may be used to separate dust from a gas and inertia to separate heavy ore from ground rock.

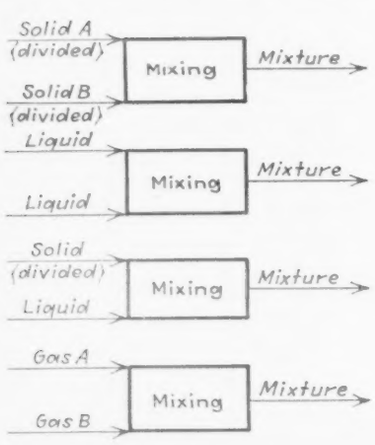
FILTERING Filtering is separation of a divided solid from a liquid by pressing the mixture against a porous or perforated filtering medium. The force may come from hydrostatic head, air pressure or vacuum. The process may be continuous, as with rotary filters. Centrifuges use centrifugal force to multiply gravity in the separation of liquids from solids and the same centrifugal force to drive the liquid through the basket filter.

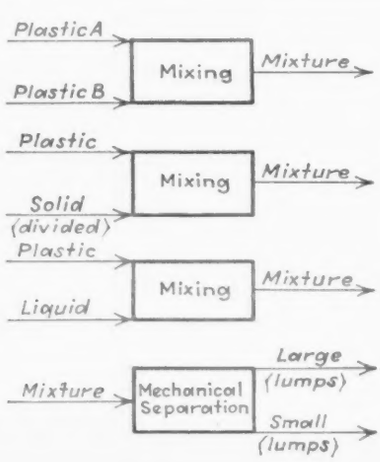
WASHING AND LEACHING Washing and leaching are also methods of separation. Washing removes soluble matter and insoluble particles, also clinging liquids. The product desired may be the solid washed or the material carried off by the wash liquid, or both.

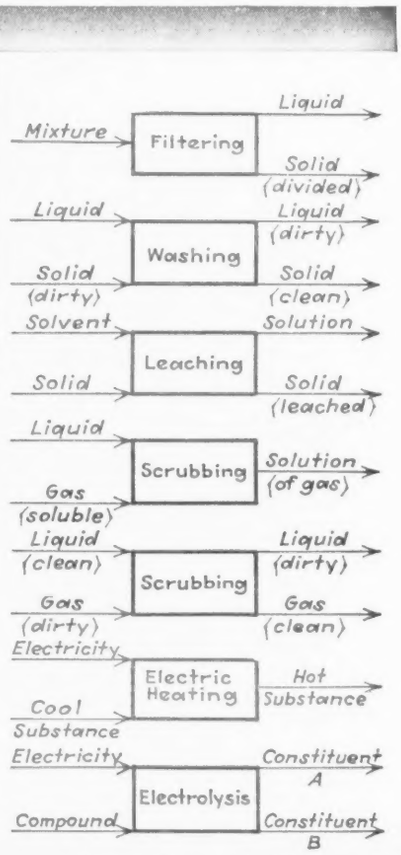
Leaching is the separation of soluble solids from insoluble by a solvent as when water trickles through a barrel of wood ash. The product to be recovered may be either the insoluble matter, or the soluble, or both.

GAS SCRUBBING Gas scrubbing is passing a gas through sprays or over wet surfaces. Other liquids than water may be used. Chief uses are dust removal and absorption of a gas to be recovered (as ammonia in water).

ELECTRICAL Electrical processing may involve the application of heat from resistance coils. Heat may also be produced by passing the current directly through certain products or by inducing a current in a conducting product or container from a surround a.c. coil. Electrolysis is the breaking down of a chemical compound by passing a direct current directly through it. It also involves the transportation of the breakdown products, as in electroplating. Electric furnaces immerse electrodes in fused solids (generally). Their effect ordinarily combines electrolysis with heating.

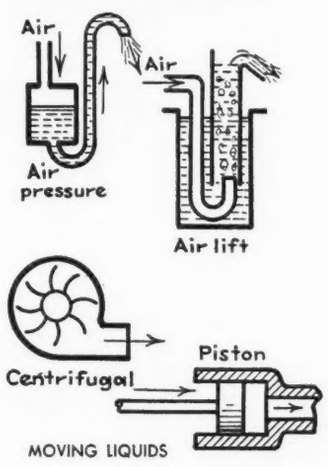






1. BASIC PROCESS EQUIPMENT

PREVIEW OF BASIC EQUIPMENT



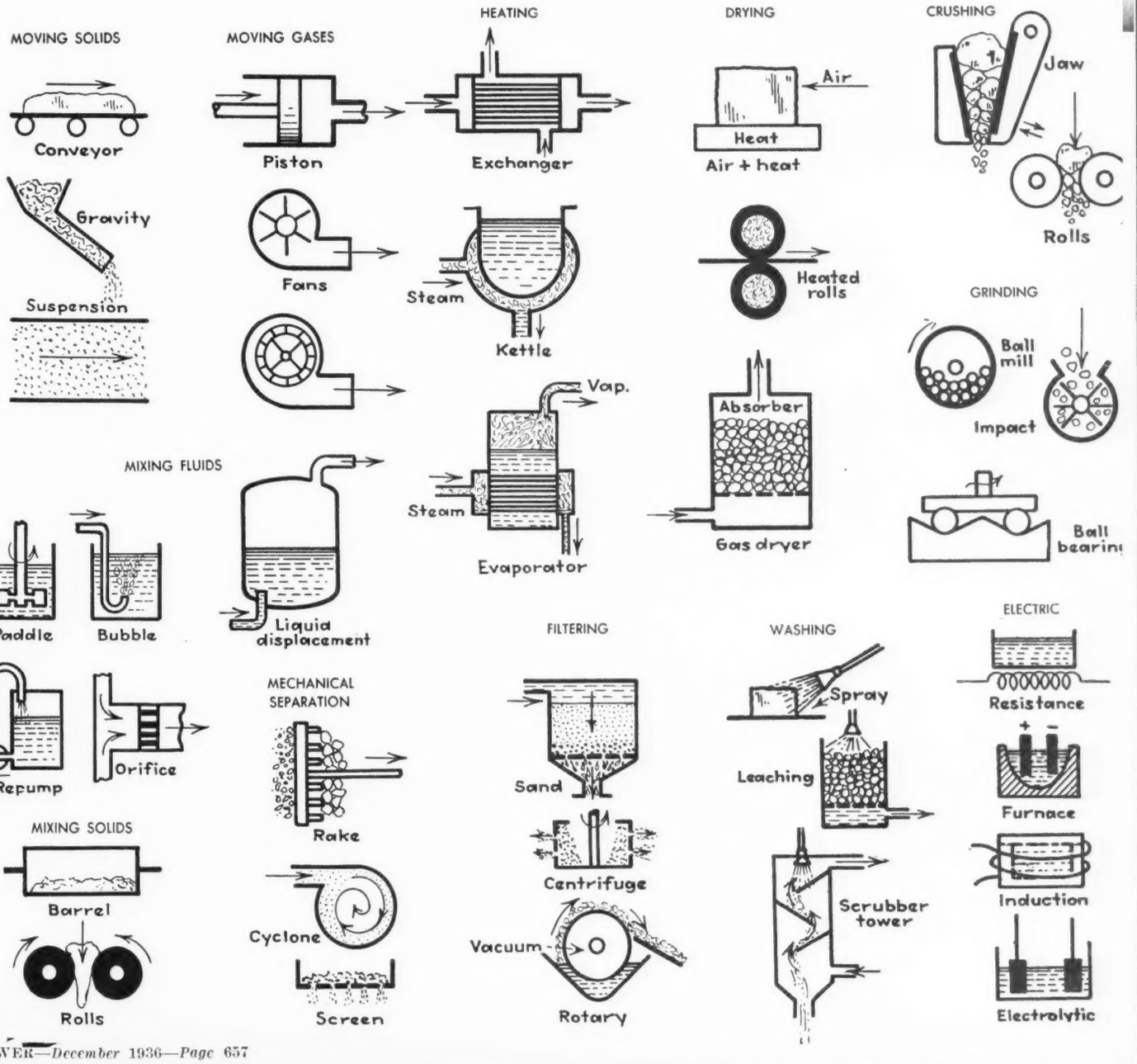
THE two preceding pages have outlined in elementary form the unit process operations found in all industries. The aim has been to show the principles involved rather than the construction of the equipment used. Next, logically, would come working drawings of all the principal process equipment used in industry. This, however, is completely impossible in the space available, because much of this equipment is highly specialized and varies in detail from industry to industry.

However, we can here go several steps beyond the presentation of principles by reducing the various types of process equipment to simplified forms, minus all structural details, but bearing a general resemblance to commercial equipment. Thus we shall create convenient mental pigeonholes for any type of equipment.

In their earlier forms most process equipment was developed from such humble origins with little more than the application of horse sense, mechanical ingenuity and experience. In recent years, however, some of these devices (but not all) have benefitted greatly by the application of scientific knowledge.

Much of this knowledge is still in an empirical state; the theory is confused. For that reason it is difficult to predict operation of many types of process equipment where size, design or working conditions step away from experience.

Since experience is of prime importance in process work, there is a tendency to pattern one plant after some other that has been successful. Thus the paper industry, to take one example, gradually accumulates over many years a group of workable devices for digesting, washing,



mixing, calendering and so on. A new mill, to play safe, will adopt most of these tested forms of equipment, perhaps making a few cautious innovations in detail.

But an industry learns not alone from its own experience, but also from that of other industries. After all, conveying is conveying, whether you are handling gravel or some granulated chemical. A boiler draft fan may be just the thing to force air through a drying room. A vacuum evaporator designed to concentrate sugar solutions without burning or caramelizing the sugar may have something to offer the dairy manager who wishes to condense milk without undue change in flavor. Stirring is stirring everywhere, if you have had enough experience with different combinations of liquids and divided solids. So it goes.

Recognizing this fact, process engineers have developed the concept of "unit operations." As was pointed out in the previous article, this expression stands for a manner of thinking—a new method of making a moderate amount of basic information do a lot of work. It makes information developed in one industry easily applicable to another. It also makes possible these brief summaries of unit operations and basic equipment. Instead of describing a dozen operations in each of a hundred industries we have selected a few main headings covering the great majority of actual operations in all process industries. Breaking these down in terms of equipment, we show 62 simplified sketches, enough to give a fairly comprehensive picture of the fundamentally different ways in which the process job can be done.

Such a summary will not produce a process expert, but should give the reader a framework on which to hang detailed information as he picks it up from manufacturer's catalogs and practical experience.

MOVING SOLIDS

The belt conveyor (Fig. 1) is widely used for conveying solids in lump or ground form. The material of the belt must, of course, be such that it will not be damaged by the product handled. This caution is necessary in connection with all types of process equipment.

For the handling of divided solids the flight or drag conveyor (Fig. 2) has many process applications. If given a reciprocating motion it may also serve as a mixer. Power requirements are higher than with belt or bucket conveyors. It cannot be used where the material or product would be injured by abrasion.

The screw conveyor (Fig. 3) not only keeps the solids, or mixture of solids and fluids, in motion, but also provides considerable agitation which may be very helpful in certain processes. It is particularly useful as a feeding device. The conveyor may be completely enclosed with the screw shaft passing out to the drive through a stuffing box.

The bucket conveyor shown in Fig. 4 is very widely used as an elevator for materials in lump or granulated form. It is particularly useful for elevating material dumped into a track hopper or raising material from the bottom of a silo.

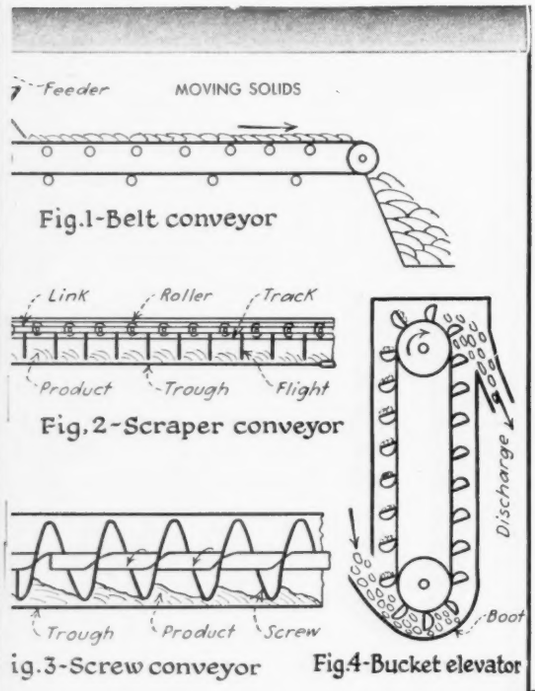
These are just a few samples of conveyors for solids. Solids can also be handled in cars, pushed by hand, pulled by locomotives or chains, driven by motors on the vehicle. Other methods of moving include trucks, grab buckets, line scrapers, rotating tables.

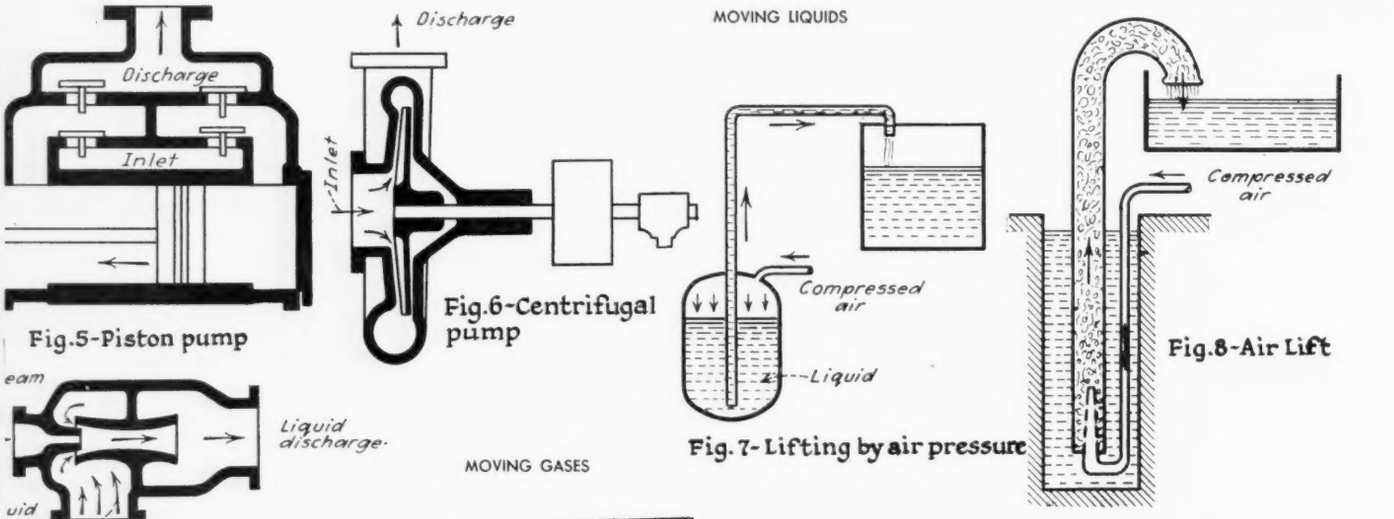
Divided solids can be transported suspended in a stream of air or water. It is not often realized that the pump and the fan are primary means for transporting solids in industry.

MOVING LIQUIDS

Piston pumps, typified by Fig. 5, are widely used, but less so than the centrifugal pumps. The centrifugal pump has a particular advantage in handling liquids containing solids in suspension. It is also generally cheaper per unit of capacity and can often be more easily adapted by special materials to the handling of corrosive substances. Piston pumps (that is pumps with pistons and rods) may be double acting or single acting. They may be direct driven by steam pistons or through crank and connecting rod.

The plunger pump is merely a piston pump with the rod expanded to the diameter of the piston. Outside packing





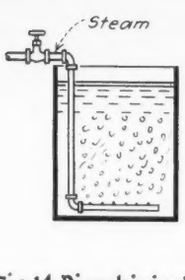


Fig.14-Direct injection

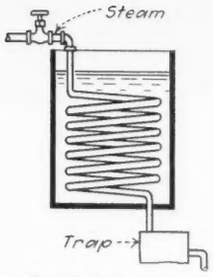


Fig.15-Submerged oil

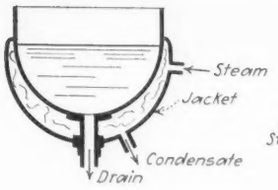


Fig.16-Jacketed kettle

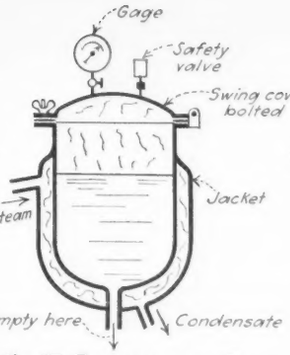


Fig.17-Pressure cooker

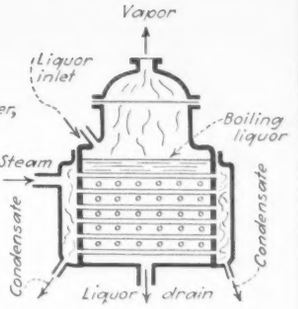


Fig.19-Evaporator

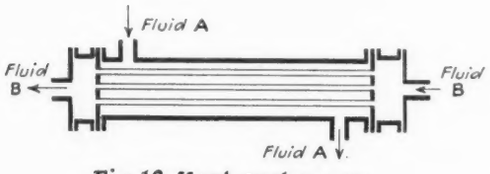


Fig.18-Heat exchanger

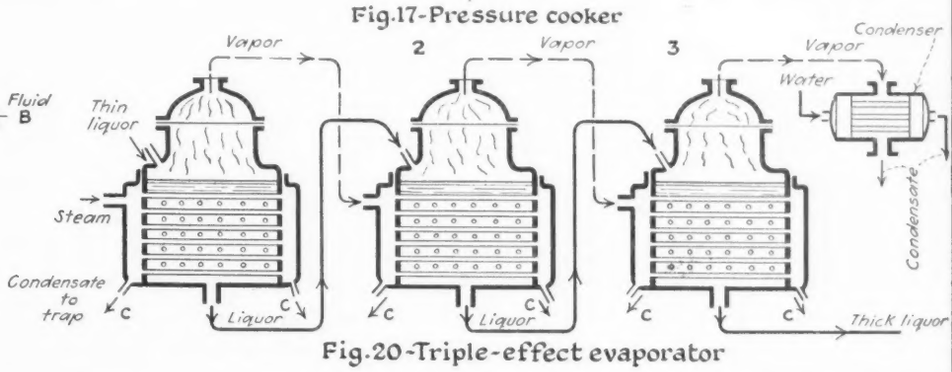


Fig.20-Triple-effect evaporator

makes leakage immediately noticeable. The geared triplex crank-and-plunger pump has many process applications, particularly for pressures so high that a multi-stage centrifugal pump would be cumbersome.

Fig. 6 pictures a centrifugal pump with overhung impeller. This design, while unbalanced, had many process applications where it is important to reduce leakage. The pressure produced by a single given impeller is about in proportion to the square of the r.p.m. When the speed limit of one impeller is reached, higher pressures can be attained by placing pumps in series or using multi-stage pumps, preferably the latter. The present trend in high-pressure centrifugal pumps is to raise the speed and use fewer stages.

Lifting by air pressure (Fig. 7) has many important applications in the handling of corrosive liquids, such as acids. The air lift (Fig. 8) is used mainly to bring water up from fairly deep wells. The large pipe is submerged a considerable distance below the water surface and a quantity of air is bubbled into the water inside the open lower end. This produces a frothy mixture which, being much lighter than water alone, rises far above the free-water level in the well. For an air lift to operate, the vertical distance from the bottom of the pipe to the discharge must bear a ratio to the submergence of the pipe considerably less than the ratio-of-water density to the density of the air-water mixture in the pipe.

Readers will recognize in the ejector (Fig. 9) a replica of the steam injector sometimes used for boiler feed. For proper working, the liquid pumped must be water or a solution largely water, so that the steam from the jet will condense as it mixes with the liquid. This is a costly method of pumping and is justified only for unusual conditions—for example, where the heat from the steam is needed and could not be obtained more cheaply from other sources, such as exhaust steam.

MOVING GASES

As was the case with solid and liquid handling, most of the equipment used to handle process gases is already familiar to power engineers. For example, the gas pump shown in Fig. 10 is exactly like that frequently used for vacuum heating systems. With the superficial appearance of a centrifugal pump, it is actually a displacement type of gas pump. Water whirled around with the impeller alternately moves in and out between the vanes as it follows the walls of the eliptical casing. It is moving out as it passes the inlet ports and in as it passes the discharge ports, thus producing a pumping action similar to that in a piston pump. Where the nature of the gas evacuated requires it (as in some chemical operations) other liquids than water can be used.

The straight-blade blower (Fig. 11) and the multi-blade fan (Fig. 12) are again familiar to readers from their use as draft fans and for ventilating and air conditioning. Their application to process gases (including air) is exactly the same except that consideration must be given to corrosive and erosive effects. Many types of positive-displacement blowers are available for low-pressure work. Although it is inclined to be both inefficient and noisy, that shown in Fig. 13 has been used for many years in foundry practice.

In recent years great progress has been made in the design of high-speed turbo-compressors for pressures as high as 100 lb. per sq. in. Similar to steam turbines in design and construction, these are costly machines, but efficient and sometimes more economical than piston air compressors for handling enormous volumes of air or gas. Space does not permit showing a sketch of this or of the piston-type air compressor or gas compressor. Piston compressors may have one or many stages according to the pressure desired. Intercooling between stages saves power and makes compression safer. Compressed air, as a power service, is discussed on page 650.

Germany is making considerable use of the free-piston diesel air compressor, a unit without cranks, shaft, connecting rods or wabble plates. With stepped air pistons, this machine can be multi-staged for high pressures.

HEAT TRANSFER AND EVAPORATION

The principles of heat transfer have already been discussed at length. Water or water solutions may be heated with little investment by bubbling in steam directly through a perforated pipe (Fig. 14). The operation is highly efficient as long as steam is admitted no faster than it can be absorbed. As the water approaches the boiling point there is danger of serious waste unless the steam valve is closely watched. With a jacketed kettle at low steam pressure, the heat supply would automatically reduce as the product temperature approached 212° F. Other disadvantages of direct injection are noise and vibration, dilution of the liquid with condensate, and contamination of the liquid with steam impurities.

More common methods of heating solutions are the submerged coil and the steam-jacketed kettle (Figs. 15 and 16 respectively). The coil has the thermal advantage that no heat is lost to the surrounding air from steam-heated surfaces. However, the kettle itself may be nearly as hot, so the difference may not be important, particularly with good insulation in both cases. All steam heated kettles should be heavily insulated to avoid very costly heat losses and preserve comfortable working conditions. The insulation should generally be jacketed with metal or other waterproof material. With many foods and sticky materials, or where the kettle must be emptied and cleaned at regular intervals, the jacketed kettle has obvious practical advantages. All heat-transfer apparatus using steam must be trapped for removal of condensate without loss of steam.

As pointed out in the article on heat transfer (page 653) the housewive's practice of cooking all liquids at 212° F. is not necessarily the best, but a matter of convenience. Where higher or lower cooking temperatures produce a better product, a device like the jacketed pressure cooker (or vacuum cooker) of Fig. 17 should be

used. With water in the kettle, the pressure inside cannot exceed the pressure of the steam in the jacket, for the temperatures equalize at that point. Actually, the steam pressure must be somewhat higher than the desired cooking pressure to maintain a working temperature difference.

With large masses of saturated liquid, pressure cookers are hazardous pressure vessels requiring careful design and protection against over-pressure. In all cases they should be provided with pressure gages and dependable safety valves of ample capacity. Pressure must always be released before opening.

By connecting the vapor space to a vacuum line such a kettle may be operated under vacuum to cook mixtures at low temperature where the temperature of atmospheric boiling would damage the product.

A typical heat exchanger for transferring heat from one fluid to another (either gas or liquid or both) is shown in Fig. 18. For maximum effectiveness the fluids should move counterflow. With parallel flow it is impossible for the heated fluid to reach a temperature above the outlet temperature of the heating fluid. With counterflow operation it is possible to bring the heated fluid within a few degrees of the inlet temperature of the heating fluid. See page 653 for heat-transfer calculations and coefficients.

Evaporators, operating in a great range of pressures from high pressure to high vacuum, are very widely used in industry. In principle and appearance they are similar to the evaporator used for boiler feed makeup, but their function is often different. The power-plant evaporator is solely for the production of a pure vapor to be condensed as distilled water. The process evaporator may separate any fluid in vapor form from its liquor. It may be operated to conserve the pure liquid or to concentrate the liquor, or both. It may be necessary to operate under considerable vacuum, as in the concentrating of sugar solutions to avoid chemical changes due to overtemperature.

Multiple-effect operation (Fig. 20) feeds the vapor from one effect into the steam space of the next. This multiplies the vapor evaporated per pound of steam approximately by the number of effects. On the other hand, a multiple-effect evaporator with a given size per effect will evaporate no more per hour than a single effect. Thus first cost is directly proportional to steam economy and the number of effects to be used is to be determined by striking an economic balance between fixed and operating costs.

In power-plant practice, multiple effect is used solely for steam economy. In process work it may have an additional object, the progressive concentration of the liquor at lower and lower temperatures. The sketch shows how the liquor moves from one effect to the next as it gets progressively stronger by evaporation.

DRYING SOLIDS

Solids are commonly dried by currents of air, preferably heated air. Even where

DRYING SOLIDS

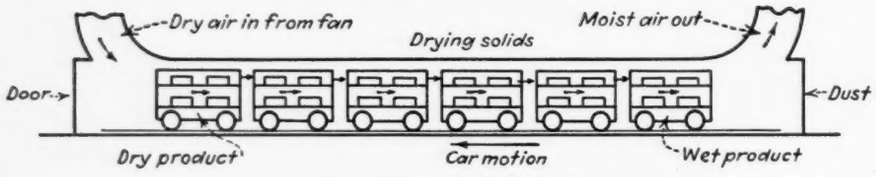


Fig.21-Tunnel dryer

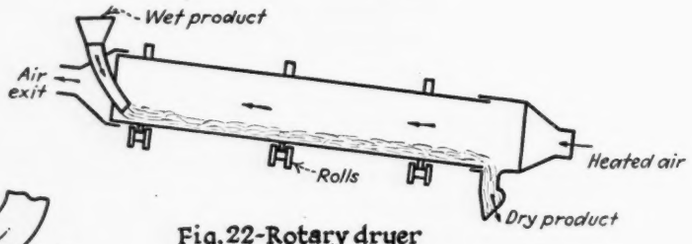


Fig.22-Rotary dryer

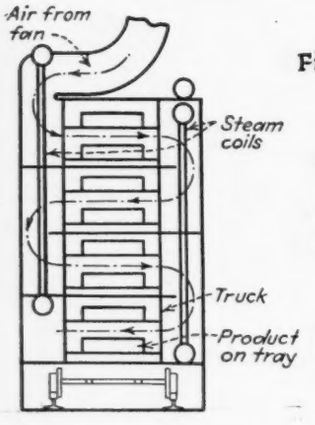


Fig.23-Tray dryer

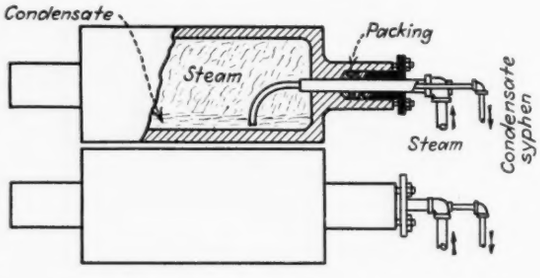


Fig.24-Steam-heated rolls

GAS DRYING

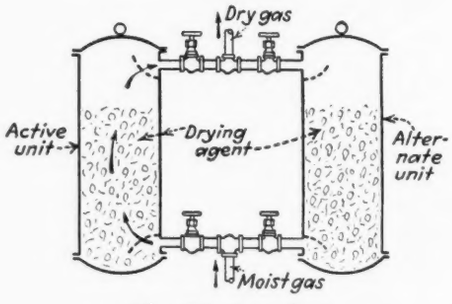


Fig.25-Gas drying

CONTROLLED ATMOSPHERE

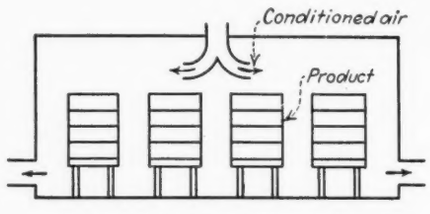


Fig.26-Air-conditioned room

CRUSHING, DRYING

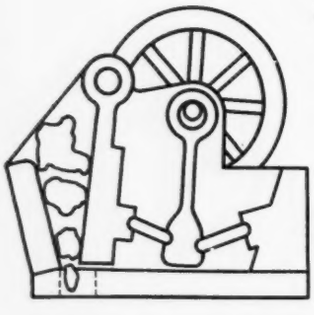


Fig.27-Jaw crusher

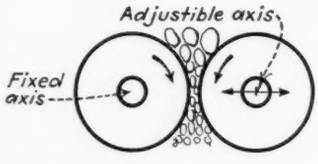


Fig.28-Crushing rolls

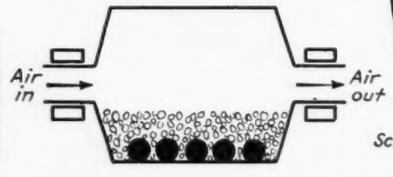


Fig.29-Ball mill

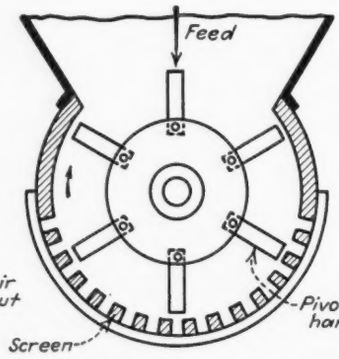


Fig.30-Impact mill

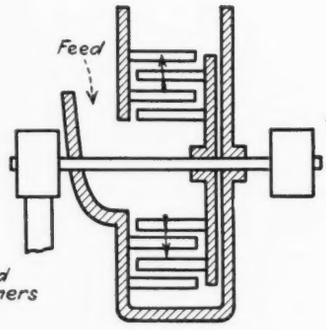


Fig.31-Attrition grinder

MIXING SOLIDS

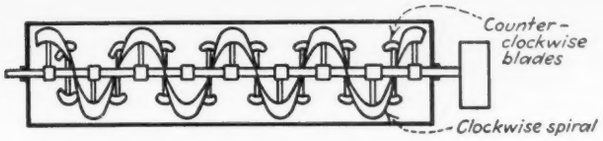


Fig. 32-Dry mixing trough

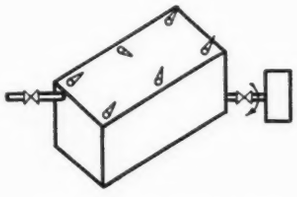


Fig. 33-Tumbling barrel

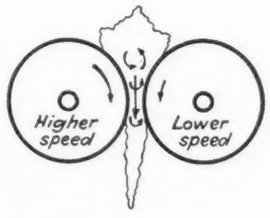


Fig. 34-Roll mixer

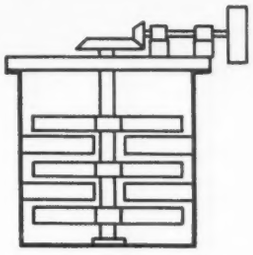


Fig. 35-Paddle mixer

Fig. 36-Stirring plus scraping

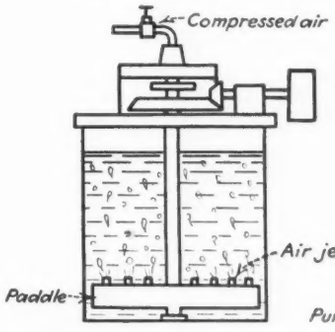


Fig. 37-Paddle and air stirrer

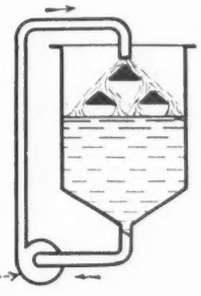


Fig. 38-Repumping

MIXING GASES OR LIQUIDS

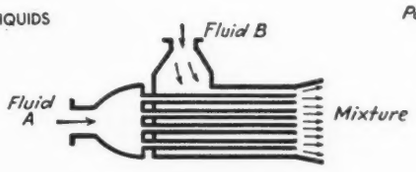


Fig. 42-Multijet mixer

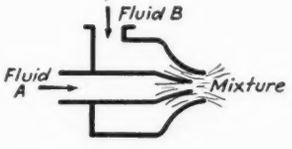


Fig. 41-Jet mixer

Fig. 44-Adjustable-orifice mixer

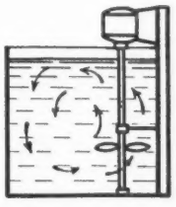


Fig. 39-Propellor stirrer

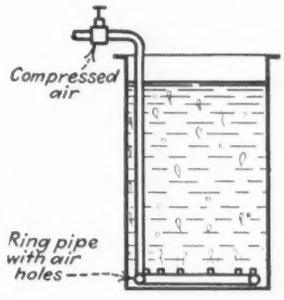


Fig. 40-Mixing with compressed air

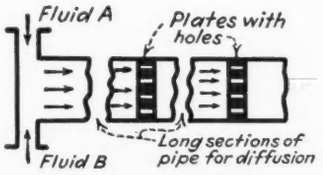


Fig. 43-Perforated-plate mixer

the outside air has nearly 100% humidity it can be given considerable drying capacity by heating. This heating, of course, does not dry the air in the sense that it reduces the weight of moisture contained. What it does is to make the existing moisture a smaller fraction of what the air can hold. Further discussion of this will be found on page 651.

There are occasions when the necessary air temperature would be damaging to the product. In such cases it may be necessary to remove moisture by cooling the air below the dewpoint before reheating it to working temperature. The air may also be dried by silica gel.

The solid product to be dried is generally stacked on trays in a drying room. These trays may be carried on cars (Fig. 21) or on some other form of conveyor.

Stirring accelerates the air drying of finely divided solids by presenting new surfaces to the air. For such drying the rotary air-swept dryer (Fig. 22) is commonly used.

Evaporation cools, so the temperature of air falls as it takes up moisture. Lower temperature and higher moisture content both reduce its capacity to pick up more moisture. Stage reheating between drying passes (Fig. 23) eliminates the difficulty as far as it is due to falling temperature. This arrangement is also useful where the product would be damaged if the air were initially heated high enough to take care of all temperature drop from evaporation.

Fig. 24 shows the steam-heated roll, widely used for drying paper, textiles and other material produced in endless sheets. If the temperature is well above 212° F. the water in the product will be driven off by boiling even without the help of air currents.

GAS DRYING

Gases cannot be dried by heat. Heat merely increases their capacity to carry moisture. One way to dry is to cool below the dewpoint and condense out water. The lower the temperature the less the remaining water. Then as the gas is reheated to the desired temperature, the weight of water stays constant and the relative humidity falls rapidly. Compression before cooling increases the drying effect. If 4 cu. ft. are compressed to 1 cu. ft. they can hold only one-quarter as much water at a given temperature. Gases can also be dried by passing them over calcium chloride or silica gel (Fig. 25) or bubbling them through concentrated sulphuric acid. Possible injurious chemical reactions with the given gas must be considered.

CONTROLLED ATMOSPHERE

Fig. 26 shows conditioned air supplied to a room in which sensitive raw material or product is stored on trays. Conditioning may be designed to change the product moisture or to maintain it in its original condition.

CRUSHING AND GRINDING

Solid lumps may be crushed by jaw crusher (Fig. 27) or by crushing rolls (Fig. 28) or by a gyratory crusher (not shown). Further reduction from small lumps to powder is called "grinding." Much of the process grinding equipment is now applied to the grinding of coal and is thus familiar to power engineers. Many types were shown in *Power's* Firing Section (Sept., 1936). Sketches show some of the principles involved. The ball mill (Fig. 29) is, in effect, a cylindrical tumbling barrel with heavy iron balls rolling over and grinding the product. The impact mill (Fig. 30) hits the particles with pivoted arms. Here the inertia effect predominates. In the attrition mill (Fig.

31) occurs a combined effect, partly impact and partly rubbing of particles on each other.

MIXING SOLIDS

As has already been stated, mixing is a matter of taking one part of a mass and putting it somewhere else in the mass. This must be continued until every portion of the mass contains the same constituents or particles in the same proportions. The important thing is not the movement of the mass as a whole, but the relative movements of its parts.

Designed to mix divided solids, the device shown in Fig. 32 has two screws, (one continuous and one broken) arranged to feed nearby portions of the mass in opposite directions. For greatest effectiveness, the tumbling barrel (Fig. 33) is mounted askew so that the mass slides from one end to the other as it turns.

It is difficult to mix heavy dough-like plastics. With simple stirring they tend to move with the paddle. The rolls shown in Fig. 34 turn at different speeds, giving a twisting and folding motion. Several passes may be necessary for satisfactory mixing. Another type of plastic mixer, not shown, rotates two Z-shaped bars close together and in opposite directions. This continuously tears the plastic mass apart and puts it together in a new combination.

MIXING LIQUIDS

Paddles and stirrers (Figs. 35, 36 and 39) are common methods of mixing two liquids, or liquids and finely divided solids. The stationary blades in Fig. 35 keep the mass from turning as a whole. Compressed air may be used for agitation (Fig. 40) or a combination of compressed air and stirring (Fig. 37). Repumping (Fig. 38) is a simple and efficient method of mixing, in many instances.

MIXING FLUIDS

Various orifice devices for the mixing of gases or liquids are shown in Figs. 41, 42, 43 and 44. The last two are particularly effective and may also be used to make emulsions and mix thin pastes.

MECHANICAL SEPARATION

One type of mechanical separator is nothing but the garden rake grown up and operated by power. The rake (Fig. 45) must be lowered by power on the working stroke and lifted on the return stroke. The mechanism shown is not commercial, but illustrates the principle. Such rakes may be used to remove growing crystals from a solution.

There may be some argument regarding the inclusion of the cyclone dust separator (Fig. 46) under this head. At any rate it functions on the basis of the mechanical principle of centrifugal force.

SCREENING

Screens for grading divided solids by lump or particle size may range all the way from grizzley bars with 5-in. spaces

MECHANICAL SEPARATION

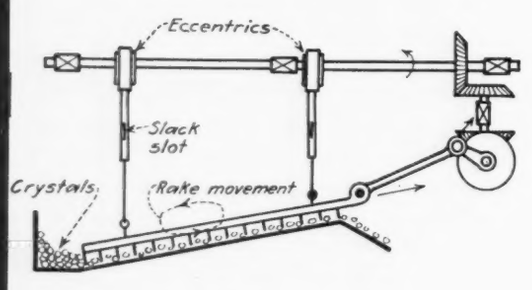


Fig.45-Power rake

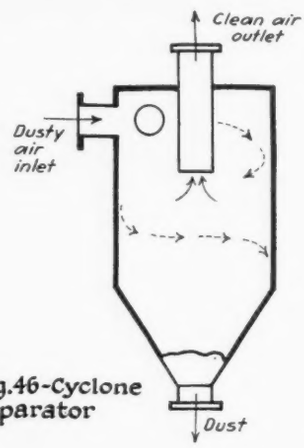


Fig.46-Cyclone separator

SCREENING

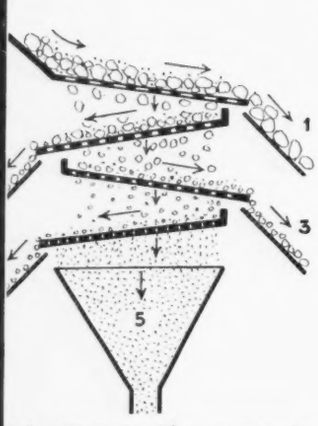


Fig.47-Selective screening

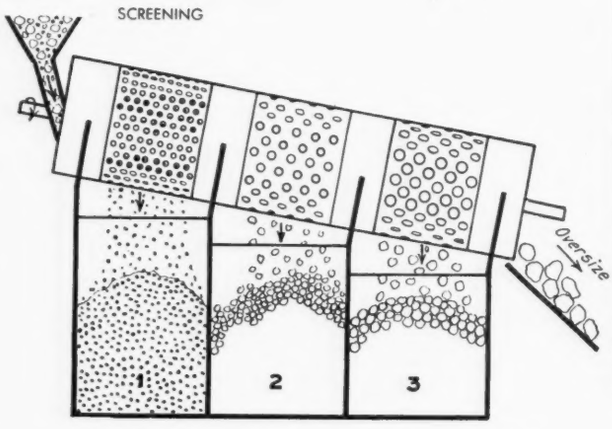


Fig.48-Trommel for graded screening

FILTERING

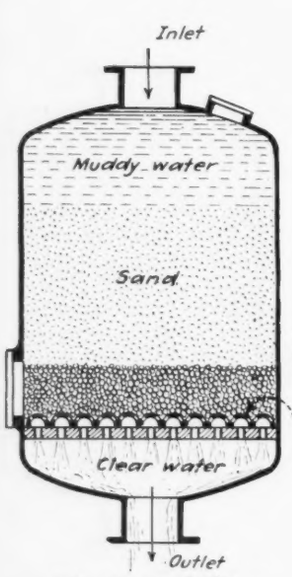


Fig.49-Sand filter

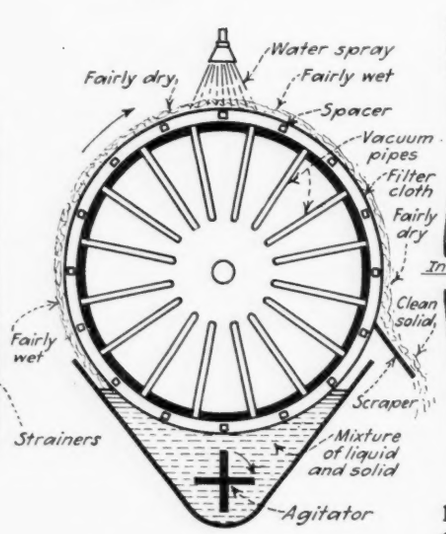


Fig.50-Continuous drum filter

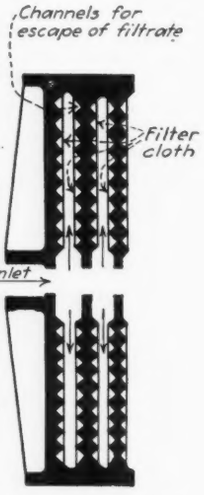


Fig.51-Sections of a filter press

CENTRIFUGING

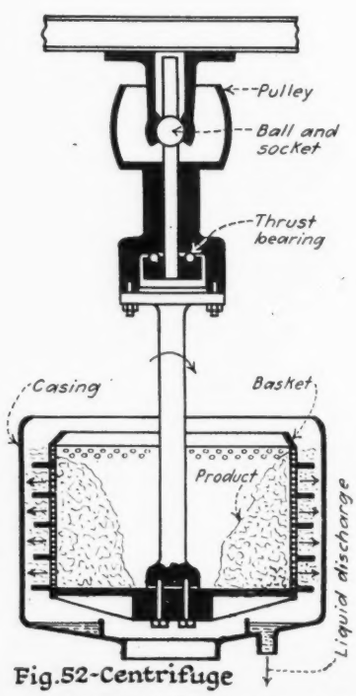


Fig.52-Centrifuge

WASHING AND LEACHING

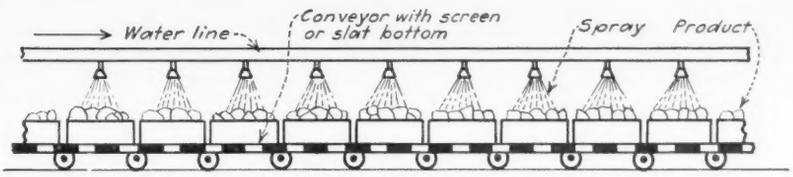


Fig.53-Continuous washer

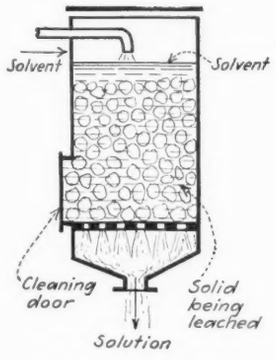


Fig.54-Tank for leaching

GAS SCRUBBING

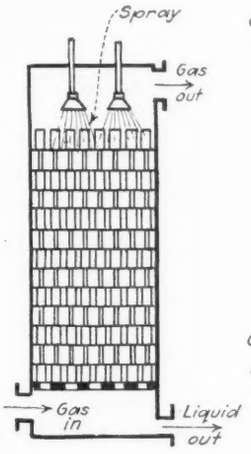


Fig.55-Spray tower with blocks

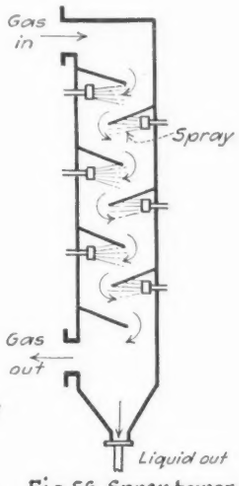


Fig.56-Spray tower with baffles

ELECTRICAL

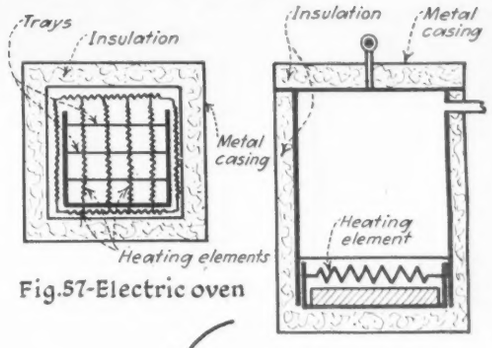


Fig.57-Electric oven

Fig.58-Electric cooker

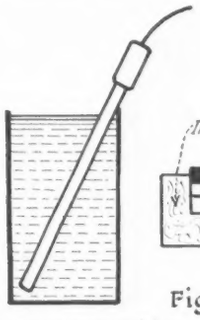


Fig.59-Immersion heater

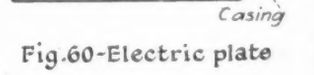


Fig.60-Electric plate

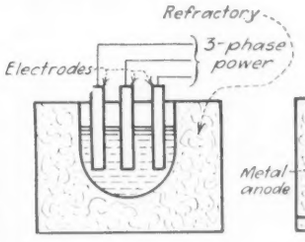


Fig.61-Electric furnace

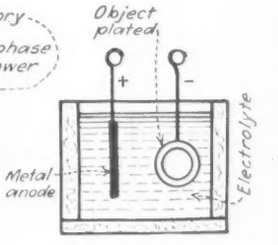


Fig.62-Electroplating

down to silk cloth of fine weave. Fig. 47 diagrams a series of successively finer screens for the selective collection of various sizes. In general such screens must be shaken mechanically to keep the material flowing down the gradual slope and to keep the openings from clogging. The trommel shown in Fig. 48 is equipped also for graded screening.

FILTERING

Filtering is separation of a finely divided solid from a liquid by passing the liquid through holes, meshes or pores too small to let the solid pass. The sand filter (Fig. 49) is effective and widely used where the object is to clarify the liquid rather than preserve the solid. It must be cleaned occasionally by an upward flow of water (backwash).

In the chemical industries a pure solid product is frequently produced by precipitation. This must be removed from the liquid and washed, after which the excess water must be removed. For this job the continuous rotary filter (Fig. 50) is widely used. The vacuum in each section is automatically broken just before it comes to the scraper.

Another common device is the filter press (Fig. 51). Many elements similar to those shown are clamped together under pressure. Thus the elements are in parallel. Each plate is equipped with channel to facilitate the passage of the liquid through the filter cloth and then along to the outlet (not shown).

CENTRIFUGING

The spinning basket or centrifuge (Fig. 52) is a device to multiply the effect of gravity. It will remove much of the liquid sticking to small solid pieces. In addition, the centrifugal force tremendously speeds up the action of the filter lining the perforated basket. Since perfect balance of the product in the basket is impossible, large centrifuges are so suspended as to find their own center of rotation independent of the axis of the shaft. Where the centrifugal forces reach dangerous proportions the guard casing should be "bomb proof." Convenient means are often provided for filling and emptying and for braking after power is shut off. Centrifuges require much time to start and stop and much power to start. The centrifugal forces go up as the square of the speed.

WASHING AND LEACHING

Washing, as illustrated by Fig. 53, is nothing but the use of a liquid (spray, dipping, etc.) to remove clinging liquid films, and solid particles, also soluble impurities. The product to be recovered may be either the material washed or the material carried away by the washing liquid.

Leaching (Fig. 54) is a variation of washing in which water or other solvent passes through a solid containing a soluble constituent which is to be removed. The product to be recovered may be either the dissolved solid or the residue, or both.

GAS SCRUBBING

Common forms of gas scrubber are the spray tower (Fig. 55), fitted with blocks, and the baffled tower (Fig. 56). The obvious purpose is to bring the gas into intimate contact with the water or other washing liquid. Such towers may be used to recover a desirable gas or remove an undesirable gas by absorption of the gas in the liquid. Scrubbers are also widely used to remove dust and tar from gases and dust from air.

ELECTRICAL

Various arrangements for electric heating by resistance coils are shown in Figs. 57, 58, 59 and 60. The first two indicate very heavy insulation because of the high energy cost of electric heat. In general it can be used only where its application is far more efficient than that of competing methods of heating.

The induction furnace (not shown) creates heat by eddy currents induced in the receptacle or the substance heated by means of alternating current in a coil surrounding the retort. The heat comes from the inside out, not from the coil itself. This is the industrial equivalent of the "fever machine," and is now widely used for melting brass and other metals.

The electric furnace (Fig. 61), used to manufacture Carborundum and many other substances, immerses the electrodes directly in the molten material.

Whole industries have been founded on electrolysis, the breaking up of chemical compounds by the passage of a direct current. Fig. 62 illustrates a plating bath, an important electrolytic application.

For example, the anode may be copper and the solution be saturated copper sulphate in dilute sulphuric acid. Direct current passing from anode to cathode causes copper to deposit on the object to be plated, while the anode dissolves.

2. APPLIED MECHANICS

ON page 652 were summarized many basic laws of mechanical power. Supplementing these, the present brief article presents a miscellany of useful mechanical rules, kinks and computing methods. This is little more than a very rapid review of some elementary facts of every-day mechanics, but these facts have many important applications. In getting a process into working shape it is often necessary to rig up home-made attachments in the shape of cams, linkages, pistons, etc.

FIG. 1—Epicyclic gear: If *A* is stationary and *B* swings around on arm, *B* makes one more revolution per circuit than it would if the arm stood still and *A* turned. *B* makes two complete revolutions in one revolution of the arm.

FIG. 2—Gear train: Speed of output shaft equals speed of input shaft multiplied successively by the teeth ratios of driver to driven gear in every meshing pair.

FIG. 3—Pantograph: If *d* follows any profile *e* will trace exactly the same shape in reduced size. Tracing 2 will be to tracing 1 as *cf* is to *df*. Side *B* must be equal to *D*, and side *A* must be equal to *C*. Moreover the two tracing points must be in a straight line with the pivot.

FIG. 4—Leverages: Force on one side times its perpendicular distance from the fulcrum, equals the same for the other side.

FIG. 5—Instantaneous center: At any given moment a moving body is rotating about an instantaneous center. If you draw a line from this center to any point in the body, the line will be a radius and the point will move at right angles to it. Conversely, if the direction of motion of any point in a body is known, a line drawn at right angle to it must be a radius. The intersection of two such radii will locate the instantaneous center. The speed of each point is proportional to its distance from the center. Thus the velocity of *B* is to the velocity of *A* as *BC* is to *AC*.

FIG. 6—Linkwork: The motions in any linkwork can be found by applying the principle of instantaneous centers. Start with the instantaneous or permanent center of the first lever or link. From the known velocity of some point in the link find the velocity of the pin joining the first link with the second. This gives the velocity of a point in the second link and helps to get its instantaneous center in turn.

In the example shown the links are the heavy lines *A,B,C,D*. Fixed pivots are double circled. Movable pivots are single circled. Arrows show the velocities to scale at various points. The only given velocity is "1." From this all the others are determined by following through, in order, the constructions numbered 2,3,4 and so on. Draw 2. By simple proportion we get 3, the velocity at the juncture of *A* and *B*. The instantaneous center of this point on *B* must lie somewhere on the line *A*. That of the other end of *B* must lie somewhere on the line *C*. Therefore the intersection *b* must be the instantaneous center of link *B*. Then draw 3*a* and 4 to get 5. Continue step by step until you reach the final velocity (marked "12") of the sliding member *E*.

FIG. 7—Cam layout: Plot (as in upper sketch) the desired position of the center of the cam roller for each angular position of the cam. Transfer the roller center to the proper radii on the lower sketch. Draw the cam roller to scale in each position and draw the cam profile to touch the rollers.

FIG. 8—Piston work: Average vertical measurements of pressure line to get the average pressure.

FIG. 9—Hoist: If the hand chain has to be moved 100 inches to raise the hook one inch, the mechanical advantage is 100. Neglecting friction, the weight lifted will be 100 times the pull.

FIG. 10—In a block-and-fall the mechanical advantage is equal to the number of strands of rope rising from the lower block. Three strands (as shown) multiplies force by three.

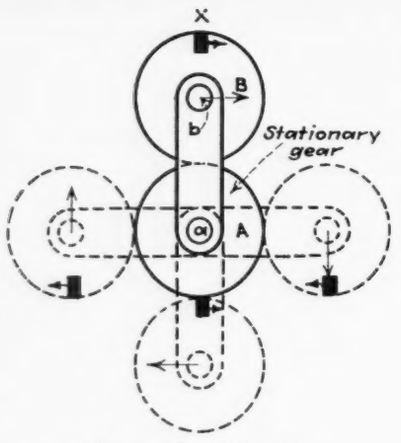
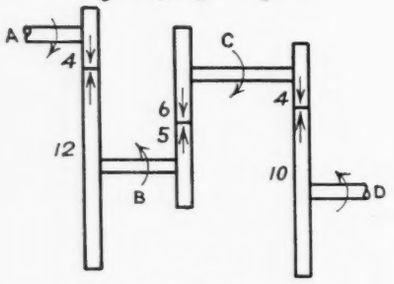


Fig.1-Epicyclic gear



If speed A = 90 R.p.m.
Speed of D = $90 \times \frac{4}{12} \times \frac{5}{6} \times \frac{4}{10}$
= 10 R.p.m.

Fig.2-Gear train

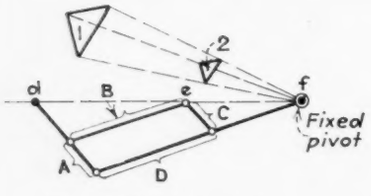
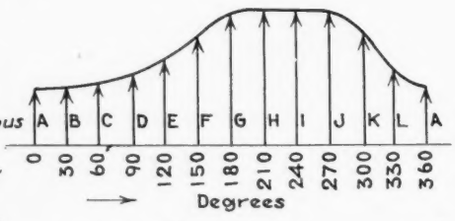


Fig.3-Pantograph

Fig.5-Instantaneous center



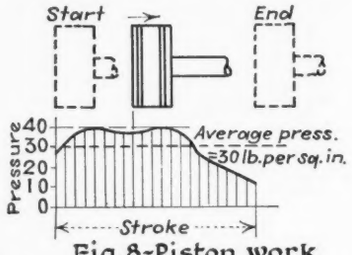


Fig.8-Piston work

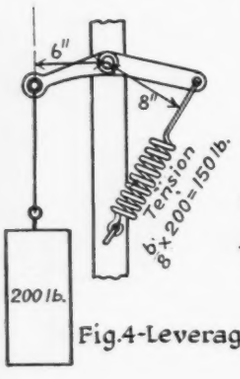


Fig.4-Leverages

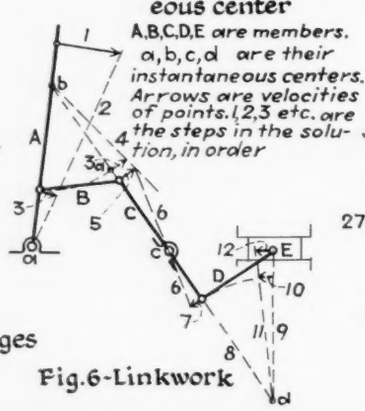


Fig.6-Linkwork

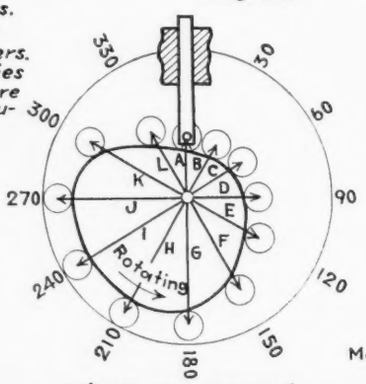
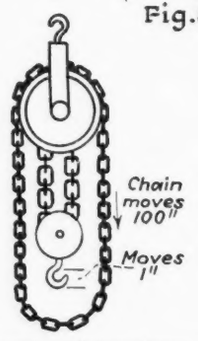


Fig.7-Cam layout



Mechanical Advantage = 100
Fig.9-Hoist

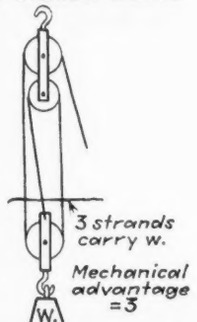


Fig.10-Block and fall

1. METERS

WHEN processes use steam, water or compressed air it is desirable for cost accounting and control to know how much they use. Flow meters measure the rate of flow of fluids and integrate it so that the quantity supplied during a given period may be determined.

Flow meters are classified as head, head-area, area, and rotary water meters. Head meters make use of a pressure differential created across a primary device of known constant cross-section area. Velocity of the fluid through the known area, and hence the volume flowing, varies as the square root of the pressure differential, which a secondary device translates into flow readings. In head-area meters, the area of the primary device changes as well as the head. In area meters pressure differential remains constant and the area through which the fluid flows varies. Rotary disk and other types of rotary meters mechanically measure a definite volume of fluid with each revolution. They count revolutions of the rotor, and from these flow during a period may be calculated.

All of these instruments measure only the volume. To determine weight it is necessary to know density. Therefore, when a meter is to be calibrated in pounds per hour, the meter manufacturer must have the pressure and temperature of the steam, air or water to be measured. If later pressure or temperature varies from those used in making up the scale, it is necessary to apply a correction factor.

Primary devices used in head meters are nozzle, thin-plate orifice, pitot tube and Venturi tube, such as those shown in Fig. 1. Nozzles and orifices are used to measure flow of steam, water and air. The Venturi tube is usually used to measure flow of liquids. The pitot tube is used mostly for air and gas.

The difference in pressure caused by the primary device is piped to the secondary device. Quite commonly this is the equivalent of a mercury filled U-tube. Pressure differential causes the mercury to rise in one leg and fall in the other. In Fig. 5*e* the rising mercury carries a float which, through a rack and pinion, turns a cam shaped to cause a pointer or secondary pen to move in direct proportion to flow. In other devices the float directly operates a pointer which, however, does not move in equal increments for equal increments of flow. In Fig. 2 the U-tube is formed by a bell. Pressure difference inside and outside the bell causes a difference in mercury level, and the bell rises. For equal increments of flow it rises equal increments, transmitted to a pointer through a lever.

Several meters (Fig. 5 a, b, c) make use of electrical transformer characteristics to translate the U-tube mercury rise into flow indications. One (Fig. 5a) uses the mercury to short-circuit calibrated resistances, so increasing current flow in proportion to fluid flow.

Fig. 5g shows a bypass meter, an entirely different type of head meter. Pressure difference across the orifice causes flow of the liquid through the bypass, causing a turbine rotor to turn. Revolutions of the turbine are counted and give direct indication of total flow.

In area-type meters fluid flows through the meter causing a plug or piston to rise, and in so doing to increase the area of the orifice through which the fluid flows. The plug maintains a constant pressure differential, hence flow is proportional to the orifice area created by the rising plug.

Head-area meters measure flow of liquid from an open tank or flume. Weirs of either triangular or rectangular shape are used as primary devices. The secondary device merely measures height of water surface above lower edge of the weir. Floats are usually used for this. Fig. 3 shows a V-notch meter with two floats, shaped and supported so that a change in head rotates a shaft in equal increments for equal increments of flow.

Fig. 2 shows a rotating-disk type meter of which there are many different designs. Flow through the meter causes the disk to wobble, operating a counter which totalizes the flow. Other types have buckets which rotate on a shaft and so dump to the meter outlet. The shaft in turning operates a totalizing counter.

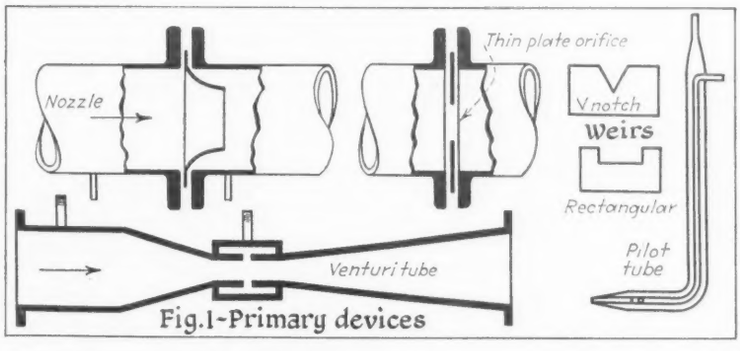


Fig.1-Primary devices

Fig.2-Rotary disk meter

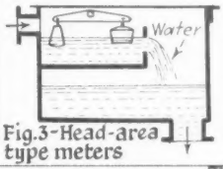


Fig.3-Head-area type meters

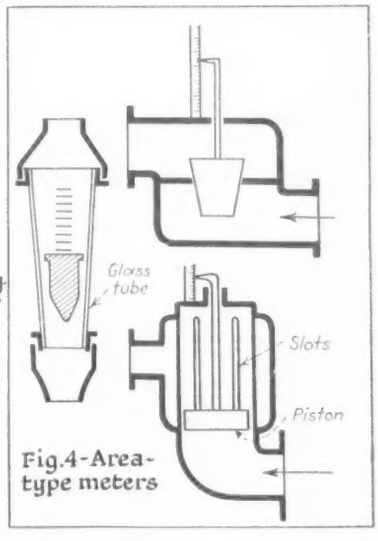


Fig.4-Area-type meters

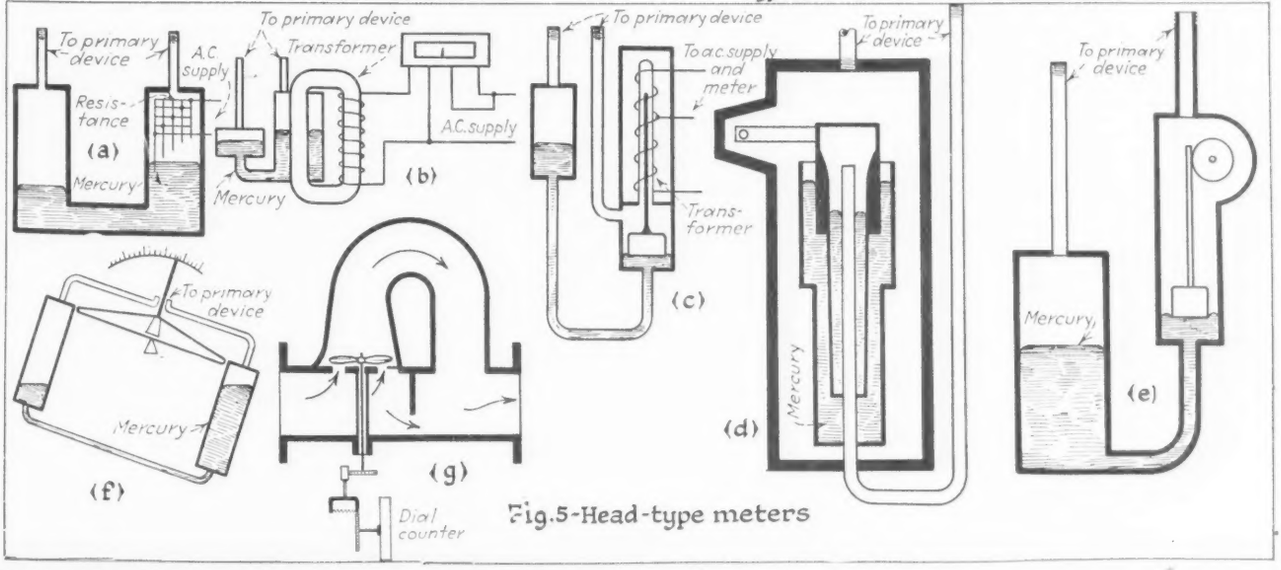


Fig.5-Head-type meters

2. CONTROL ELEMENTS

AUTOMATIC control finds its widest application in the process industries. The final product must have the right chemical composition, thickness, dryness, color, transparency, etc. In the various process steps, solids, liquids and gases must be combined or separated under predetermined conditions of concentration, pressure, temperature, liquid level, rate of stirring, length of processing period, etc. Air humidity must not be too high or too low; viscosity must fall between certain limits. All of these, and many others, can be automatically controlled.

Every control device has at least two elements—the metering or sensitive element, and the power or control element. The first sees or feels something happening; the second says or does something about it. The thing done may be applied to a cause one or more steps back.

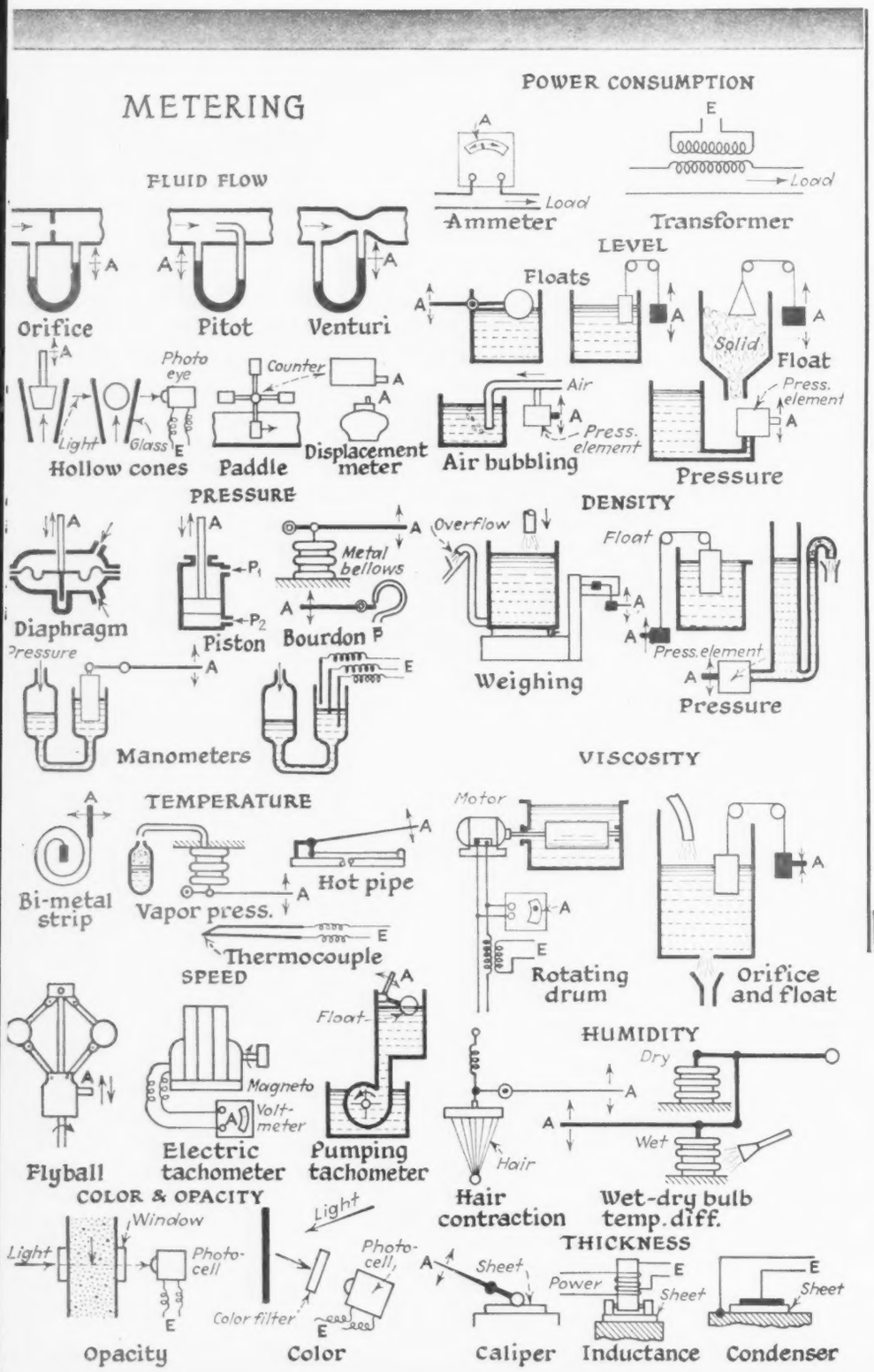
Therefore, in listing controls, it is important to distinguish between the quantity or quality being measured and the quantity or quality directly controlled. A third distinction may be made by introducing the end sought, which may in turn differ from the thing measured. For example, a machine could hardly measure the tastiness of cookies, but an "electric eye" could easily check them for proper brownness that goes with edibility, and adjust heat supply or conveyor speed.

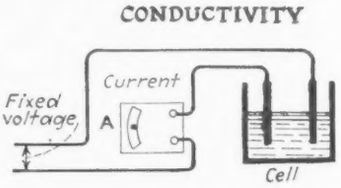
The table lists the major qualities or quantities metered and the corresponding quantities or qualities controlled. No listing is made of ultimate effects desired; they are too many and too varied.

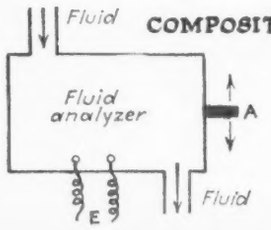
METERED QUANTITIES VERSUS CONTROL QUANTITIES

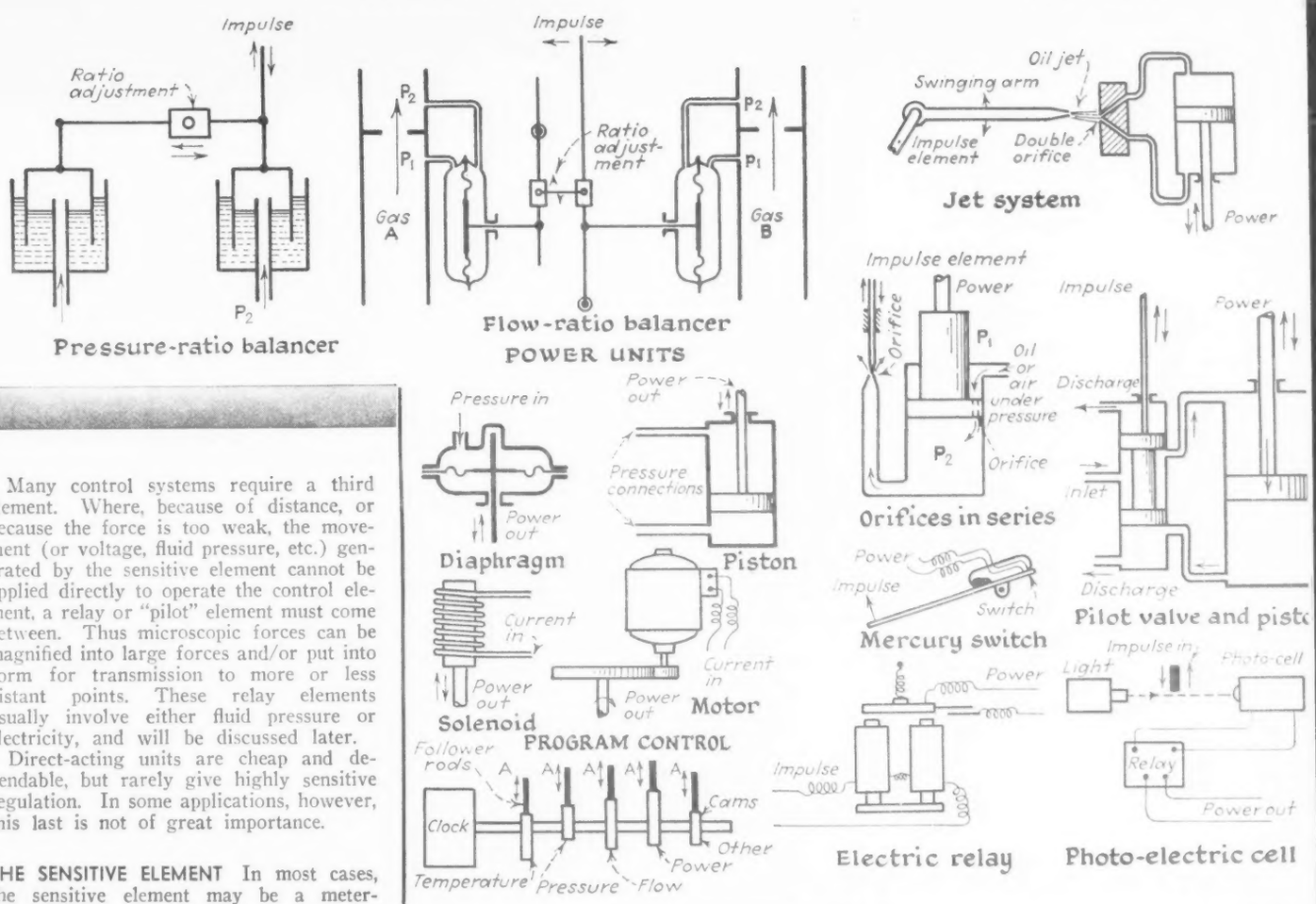
Quantity or Quality *Measured*	Quantity or Quality *Directly Controlled* (one or several of those listed)
Temperature	Fuel flow, air flow, steam flow, hot-water flow, cold-water flow, refrigeration flow, steam pressure, position of heat shields
Pressure	Pressure, supply of heat, flow of fluid, flow through vents or bypasses
Speed	Voltage, field excitation, frequency, speed ratio of power transmission
Power consumption and peak-load duration	Supply of power
Liquid level	Inlet flow, outlet flow, level of skimming drain, discharge level of submerged drain, pressure of air in tank (in turn controlled by air flow)
Humidity	Flow of moist air, flow of dry air, flow of water, temperature (controlled by flow of steam)
Hydrogen-ion concentration	Flow of acids, flow of alkaline solutions, flow of solid chemicals
Composition	Flow of various solid and liquid substances, temperature (through control of steam pressure, steam flow, etc.)
Level of solids	Inlet flow of solids, outlet flow of solids, (either controlled in turn by position of chute gates or speed of conveyor)
Thickness	Roll gap, etc.
Density	Controlled by one or more of the following: temperature, treating time, steam feed, air feed, liquid feed, solid feed, feed temperature, power or speed of agitators, etc.
Viscosity	
Opacity	
Refractivity	
Electrical conductivity	

The sensitive element is combined directly with the control unit in many cases. For example, a metal bellows partly filled with volatile liquid expands when its temperature rises, and can directly operate the stem of a small valve to shut off or throttle the steam supply.









Many control systems require a third element. Where, because of distance, or because the force is too weak, the movement (or voltage, fluid pressure, etc.) generated by the sensitive element cannot be applied directly to operate the control element, a relay or "pilot" element must come between. Thus microscopic forces can be magnified into large forces and/or put into form for transmission to more or less distant points. These relay elements usually involve either fluid pressure or electricity, and will be discussed later.

Direct-acting units are cheap and dependable, but rarely give highly sensitive regulation. In some applications, however, this last is not of great importance.

THE SENSITIVE ELEMENT In most cases, the sensitive element may be a metering or measuring element, or it may merely be a detector to indicate, for example, that a certain circuit is alive or a certain machine in motion. Many protective controls include such detectors.

The problems of lag and speed of change add many complications to regulation. Suppose an element, sensitive to electrical conductivity, discovers that the effluent from a large salt-and-water-mixing tank has too low a conductivity (meaning that the mixture holds too little salt). The sensitive element signals the salt feed to deliver more salt, but the capacity of the tank is large and the effluent shows no immediate improvement. So the element signals for more salt, and for still more. Finally, an over-salted batch reaches the meter, which then goes to the other extreme and shuts off the salt feed entirely.

This is an extreme example of "hunting." Controls must provide for it, particularly where there is a big time lag in the equipment. In this case the control should add a little more salt, wait a while before metering the result, then, if it is still low, add a little more salt, pause again, and so on. In short, a lag must be introduced either in the sensitive element, the relay or the control unit. This lag must be different for different applications.

There are two types of controller, the "2-position" and the "continuous" or "throttling." The former gives only two rates of supply, a single high and a single low. The low point is frequently zero, in which case the control is called "on and off." 2-position control is frequently satisfactory for batch operations, but where the product flows steadily in and out, throttling control is generally needed to avoid unevenness in the product.

The means for allowing for process lag are too complex to discuss in detail here. They frequently involve additional sensitive units and delay mechanisms. For example, a rate-of-change element may cause the control to slow up the rate of flow as the pressure, say, approaches the correct level. Some systems take an indication, send out an impulse, then wait a while before taking a second indication, to give the controlled action time to show its final effect. Others suit the amount of the correction to the size of the error in the metered quantity. If quantity is away off, they bring it back fast; if only a little off, slowly. If the quantity is coming up to the mark rapidly and is likely to overshoot, some apply a negative correction.

The diagrams headed "Metering" show the essential principles involved in most of the commonly used sensitive elements. No attempt has been made to show actual construction. Many of these have already been covered in the preceding article, but are included here for the sake of completeness. In each of the diagrams the spot marked "A" (the sensitive, metering or impulse element) takes a position determined by the quantity being measured, and must control the movement of a pilot or relay element. "A" normally indicates movement of a piece which can operate pilot valve, affect an electric eye, or make electrical contacts. In some cases, the letter "E" replaces "A" to indicate a purely electrical impulse.

The pilot units shown under that head take the delicate movements made by point "A" or the delicate currents delivered at "E" in the metering elements and amplify them by mechanical or electrical means. In some cases, where extreme power is needed to move heavy valves, etc., a second stage of amplification may be added.

With the aid of one or more relays or pilot elements, a heavy force, liquid pressure or electric current is built up. This then goes to the control element or power element proper. Most common forms, as shown, are diaphragms, pistons, solenoids, motors. The two former may be operated either by liquid or gas pressure, the two latter by electricity. Their stems or shafts are connected directly or by levers, wires, pulleys, gears, etc., to globe valves, chronometer valves, butterfly valves, clutches, rheostats, etc.

The first sketch under "Balancing" shows how two metering elements may be balanced against each other to maintain a constant controllable ratio between two fluid pressures. The other sketch amplifies this idea to balance the difference of one set of pressures against the difference of another set. When the two differences are in the desired ratio, the two flows (as of combustion air and gas) are in the desired proportion.

Space is lacking to discuss "program control," but its coming importance should be mentioned. A clock mechanism (generally driven by a synchronous motor) drives a shaft on which individual cams adjust settings of the individual metering elements for temperature, pressure and so on. Thus, all important variables in a process may be made to vary automatically in accordance with a program laid out in advance. Starts already made along this line indicate a coming revolution in the control of process and other manufacturing operations.

3. VALVES & TRAPS

VALVES and traps are important elements depended upon to control the flow of piped power services to and in processes. The elements of the more common valves and traps are shown in Figs. 1 and 2.

In its simplest form, a plug valve consists of a suitable housing and a plug with a hole through it. Turning the plug 90 deg. either brings the hole in line with or at right angles to the aperture, thus opening or closing the valve. The plug is usually tapered to secure a tight joint. The gate valve is arranged so that a disk may be lowered to close the flow area. Both types permit straight-through flow, hence are used where low resistance is required.

A globe valve has a plate or plug that may be screwed over or into an aperture. A needle valve is similar except in size and taper of the plug. Flow is not straight-through, hence these types offer greater resistance. It is easier to control flow through them exactly, hence they are used for throttling. Globe valves are generally not used in piping carrying liquids. The ported balanced valve is a type also used for flow control. It consists of a cylinder with V-or rectangular-shaped ports. When the cylinder is raised, the ports open to permit flow. Pressure is equal on all sides of the cylinder, thus but small forces are required to move it. This makes it suitable for application in automatic control, as are also balanced globe valves having two disks.

Check valves permit flow in one direction only. These valves are generally not absolutely tight, so where tightness is required a gate valve should be added or a more elaborate type of check used than that illustrated, which has a flap pivoted so that flow in one direction opens it while reversed flow forces it shut. Another type of check is arranged more like a globe valve, and the disk rises vertically off its seat to permit flow.

Many special-purpose valves, such as blowdown, quick-opening and safety valves employ the elements illustrated.

Trap mechanisms must open when liquid is present and close to the flow of vapor. Fig. 2 illustrates elements employed to accomplish this control.

The float trap has a ball float, which rises and falls with the level of liquid in the trap body, so opening and closing a valve. Float traps may be arranged for continuous flow or intermittent flow. The continuous-flow type discharges liquid in proportion to the flow entering the trap. The intermittent-flow type has a trip linkage between the float and the valve which trips the valve wide open when the liquid level rises to a predetermined point and trips closed when it falls to a lower level.

Both bucket and inverted-bucket traps are of intermittent-flow type. In the bucket type, liquid flows into the trap body, and spills over the sides of the bucket. The bucket, when filled to a certain level, sinks. This opens the discharge valve, and pressure in the trap blows the liquid out. Vapor entering an inverted-bucket trap forces liquid out of the bucket, causing it to float and shut the discharge valve. When liquid flows into the trap it raises the level in the inverted bucket, which when about two-thirds full, sinks and opens the discharge valve.

An entirely different principle is employed in thermostatic traps. As long as liquid is flowing the bellows is contracted and the trap open. When vapor reaches the bellows, a liquid inside is vaporized, forcing the bellows to expand, so closing the discharge valve.

Impulse and orifice traps are continuous-flow type designed so that a very small flow of vapor exists when no liquid is delivered to the trap. Both types make use of the characteristic difference in flow of steam and water.

All these traps are non-return types. The tilting trap is one form of return trap which intermittently discharges against relatively high pressure. This trap is a receiver pivoted at one end and counterbalanced when empty. When filled with liquid, it tilts, so closing a vent valve and opening a valve admitting vapor pressure. Vapor pressure forces the liquid out against the discharge head. Check valves prevent liquid from blowing back through the inlet during discharge, and a similar valve prevents liquid in the discharge piping from blowing into the trap while it is filling. Such a trap may also be arranged for non-return operation.

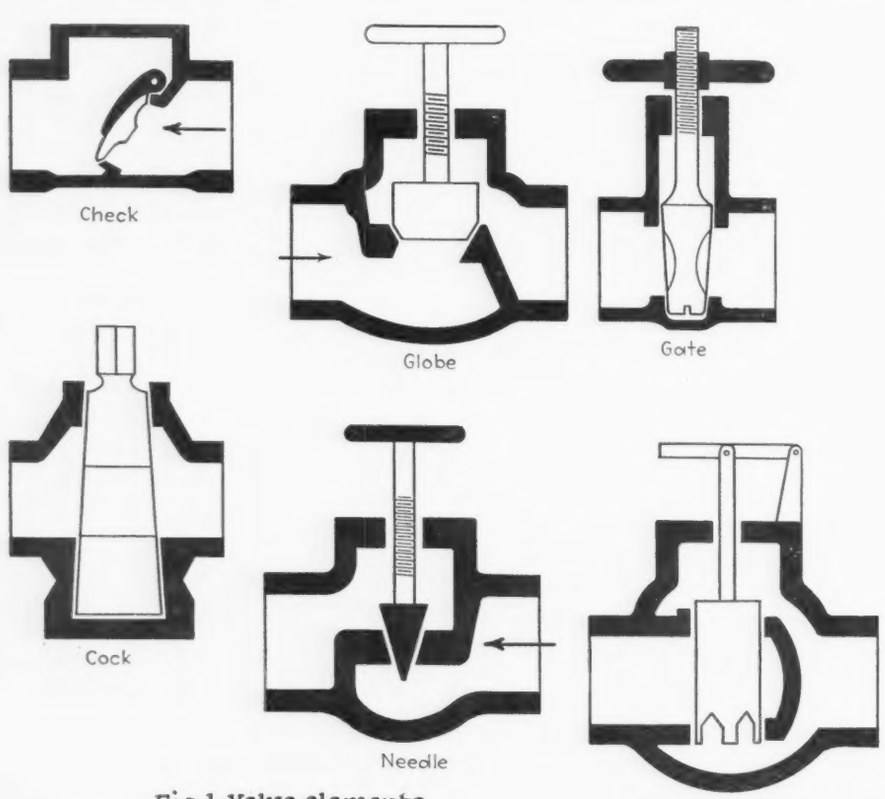


Fig.1-Valve elements

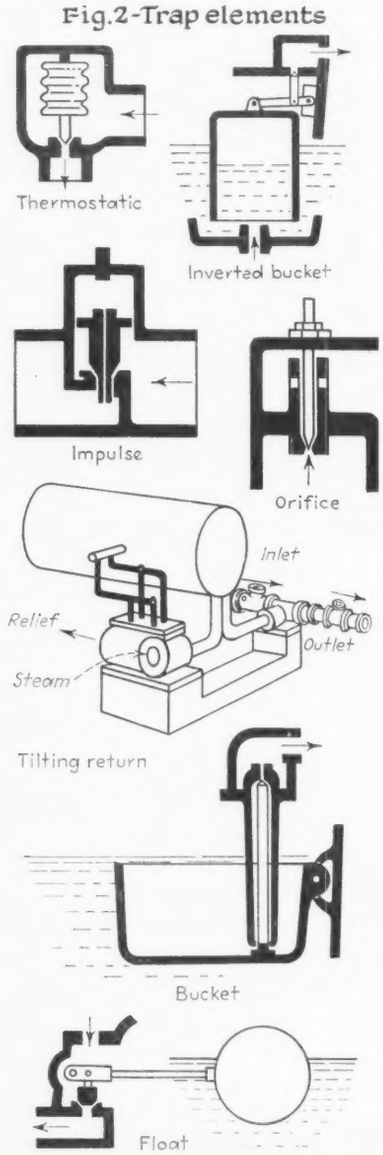


Fig.2-Trap elements

1. PIPING CONNECTIONS

ALL power services except electricity and mechanical transmission flow through pipes to industrial-process machinery. Thus piping to carry steam, hot and cold water, compressed air, and refrigerants or brine form an important part of industrial plants. Their correct design, sizing and installation are essential to continuity of operation, economy and proper process control.

For example, steam piping that is too small will cause excessive pressure drop due to friction, and as the lower-pressure steam does not provide as high a temperature as needed, the lower temperature may injure the quality of the product or increase manufacturing time. Improper provision for expansion may cause damage to either connected equipment or to piping. It may cause leaks at joints, which are not only wasteful but also may cause spoilage from drip on manufactured products. Because of an omitted valve it may become necessary to shut down a process while a mechanic makes repairs to a control valve. Improper provision for draining condensate may slow up a heating process or cause dangerous water hammer in a steam line. Insufficient insulation causes needless loss of heat and poor-quality steam at the process equipment, which usually slows up operation. These are but a few of the troubles that poor piping may cause.

The same principles apply to power-service piping as apply to the piping in the power plant where these services are produced. Best results are normally secured by having a competent engineer lay out and detail not only the main header systems, but also connections from the header to the process machines. So often this part of the piping is left to the pipe fitter to install according to his own judgment. This may work out satisfactorily if the pipe fitter has considerable experience, but more often desirable valves are omitted or poorly located and drains are forgotten. In working layouts, the engineer should endeavor to secure an installation of pleasing appearance and one in which the individual lines are easy to follow. Piping run parallel to the main building axes makes a better appearance than piping which is run at an angle.

In making connections between headers and process machines, expansion must not be neglected. Remember that a steam header, which is apt to be long, expands and the tee to which a branch connection is made may move an appreciable distance along the axis of the pipe, particularly if it happens to be close to an expansion joint. The branch pipe or machine connection should have sufficient flexibility to permit movement of the header fitting without placing undue stress on the pipe or the process equipment. Likewise, the branch piping itself expands when steam is turned on and flexibility must be provided in this direction. Note how in Fig. 11 provision has been made for expansion by elbows and the long length of vertical pipe.

When refrigeration is being piped, the design must take care of contraction. This tends to pull apart joints and so cause leaks, unless flexibility is designed in.

Pipe size, of course, depends upon the consumption of steam, air or water by the equipment served. Usually for steam piping a velocity of 6,000 to 8,000 ft. per min. will not cause excessive pressure loss, and larger pipe merely increases the first cost. Size of branch piping is usually determined by the size of the pipe connection provided on the process equipment. Larger pipe and lower velocity are required for water piping. Velocities should range from 300 to 600 ft. per min. for general service and 60 to 200 ft. per min. in brine lines. Usually velocities for ammonia refrigerant are about 3,500 ft. per min. for suction piping. Departures from these velocities are frequent in branch lines because they are short, hence involve little piping and small pressure drop even with higher velocity.

Place valves that must be operated for control or have to be opened and closed frequently, handy to the operator. If this cannot be done, provide an extension stem or some means of remote operation, such as motor or solenoid. Figs. 5 and 11 show valves so arranged. When it is necessary to throttle steam or air flow by hand, use a globe valve. Place a gate valve ahead of the globe so that the globe valve can be removed for regrinding without requiring the main steam header to be shut down. If control of an essential process is by a thermostatic valve or other automatic device, it is often good practice to provide a bypass so that hand control can be applied in case something goes wrong with the automatic device. This requires three valves, one on either side of the automatic control valve and one in the bypass. If it is not important to maintain this process in continuous operation, two of these valves may be left out, retaining only the gate between the header and the control valve. When a branch line is long, it may be advisable to install a valve in the branch at the header as well as one convenient to the process equipment. This makes it possible to shut the branch off in case a joint needs repair or an expansion joint needs repacking.

Fig. 11 shows a reducing-valve station followed immediately by a safety valve to protect the low-pressure equipment in case the reducing valve were to stick open. It is preceded by a gate valve so that the line can be shut off tight for repair either to the reducing valve or the pipeline. When two or more reducing valves are used in parallel, a gate valve is placed both before and after each one so that a defective valve can be repaired while the other is in operation. If possible, place valves in steam lines so that condensate cannot collect above them when they are closed. Where this is not possible, provide a drain.

In water lines, gate valves are used al-

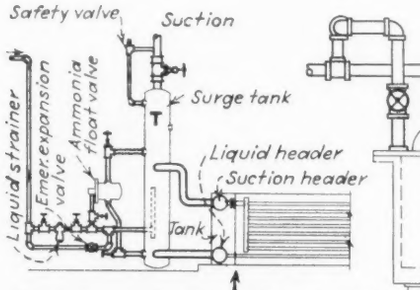


Fig.1-Ammonia piping to a straight flow coil for cooling brine in an ice tank

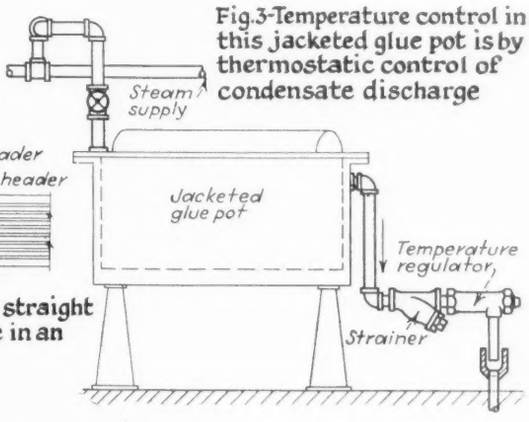


Fig.3-Temperature control in this jacketed glue pot is by thermostatic control of condensate discharge

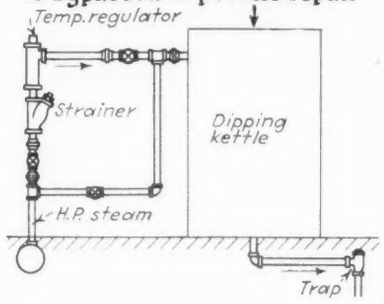


Fig.2-Piping to a jacketed dipping kettle. Control of steam is by a thermostatic reducing valve which is bypassed to permit repair

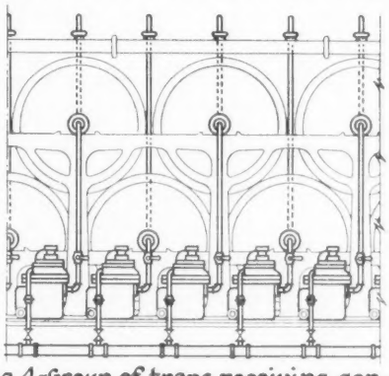


Fig.4-Group of traps receiving condensate from paper-machine drying rolls

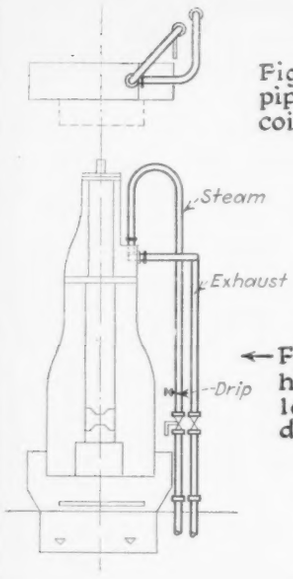


Fig.5-Steam piped to a forge hammer. Note convenient locations of valve and drip connections above it

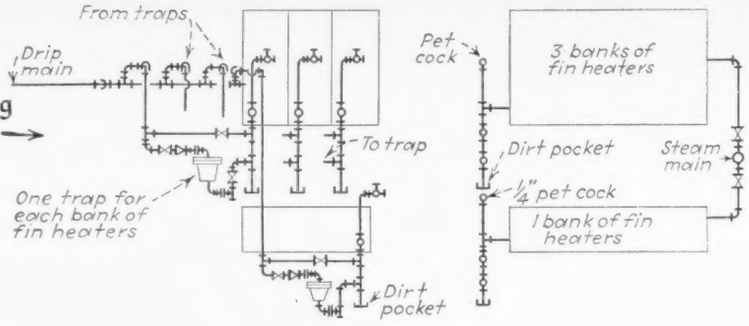
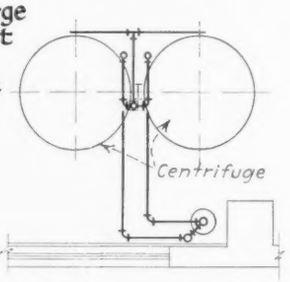


Fig.6-Steam and condensate piping to finned air-heating coils for a textile dryer →



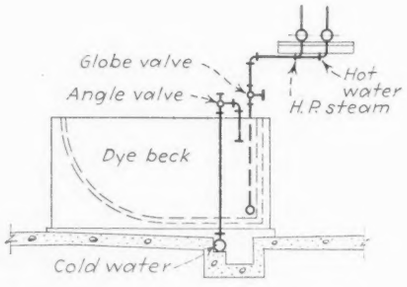
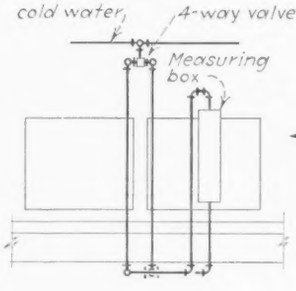


Fig.7-Steam, hot-and cold-water piping to a dye beck



← Fig.8-Piping showing method of measuring water to sugar centrifuge. The measuring box contains a piston. Water pressure on one side forces the piston down and water into the centrifuge. On the next stroke the piston is forced up

most exclusively because globe valves offer too much resistance to water flow.

Provide adequate drainage for all piping, whether steam, water, or compressed air. Also, provide drains in each section of water piping so that it can be drained when making repairs or changes without flooding the plant floor. In steam or air lines, install traps to keep the line free of condensate. When a branch connection taken from an overhead line drops down to a steam hammer or other machinery, use a trap at the head of the line to remove condensate. If the branch feeds a jacketed kettle or other similar equipment, a trap at this point may not be required as such condensate as forms can safely flow into the equipment and be drained out through the main condensate trap.

Trapping condensate from process equipment is an important part of the piping layout. Give it considerable attention. Inadequate traps or traps poorly arranged will cause sluggish removal of condensate and the capacity operation of the process equipment may be prevented. There are many types of traps to select from (see p. 668) and many ways to install them. It is preferable to place traps so that the condensate will drain into them. However, traps may be, and frequently are, elevated above the equipment drained. In this case the steam pressure must be sufficient to lift the condensate up into the trap and out of its discharge. Place a water seal and check valve in the line to the trap under such circumstances.

Often a number of similar pieces of apparatus such as heating coils, jacketed kettles or drying coils have to be trapped. Sometimes one trap of large capacity is used to remove condensate from all of them; sometimes a separate trap drains each unit. The latter method is generally preferred. If the former is used, install a check valve in the drain from each unit to prevent backflow when one unit is down.

Fig. 4 shows paper-drying rolls individually trapped. Figs. 9 and 11 show a sugar vacuum pan arranged so that condensate from each coil flows to a receiver tank. A float-controlled valve drains

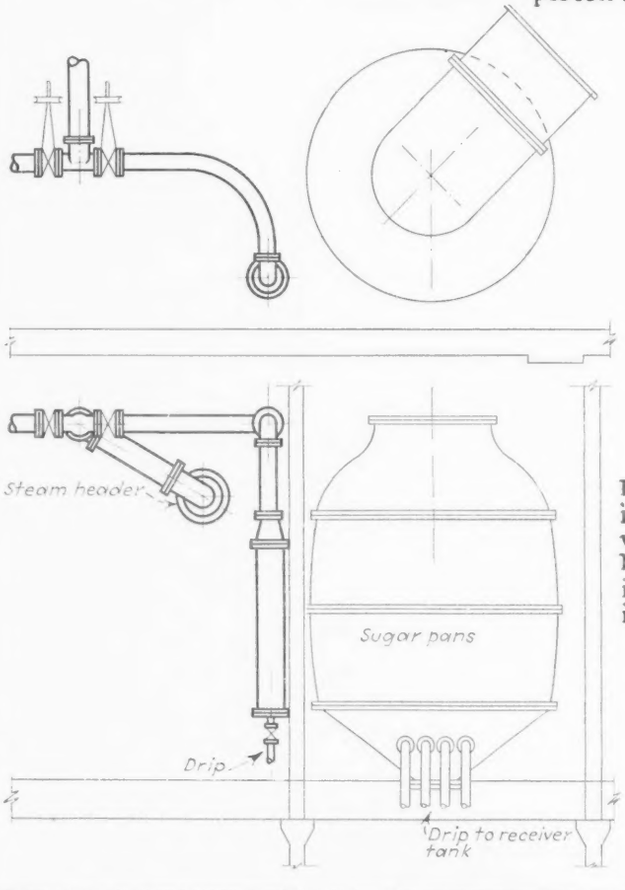
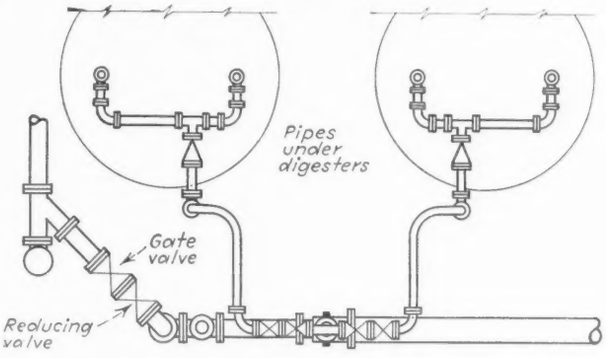


Fig. 9-Steam piping to a sugar vacuum pan. Method of removing condensate is shown in Fig.10

the receiver tank to a lower-pressure receiver, and the flash is vented to a low-pressure process-steam header. A check valve and gate are placed in each drain line to the receiver to prevent steam from flowing back to the pan coils when they are shut off.

In piping up traps, be sure that when necessary the trap working parts or the entire body may be removed without disturbing the rest of the piping. Use a union if necessary. A gate valve should be installed ahead of the trap so the trap can be shut off for repair. A difference of opinion exists among operators as to whether or not bypass connections should be provided around traps. Those who do not advocate it claim the opportunity of steam waste due to a bypass valve left open is too great. When a bypass is used, Fig. 11 shows an economical arrangement of valves and piping. When a number of traps discharge into a header under pressure, a check valve and a gate valve should be placed in the trap-discharge piping.

Material selected for piping depends on the service and the material conveyed. Pressure, temperature and likelihood of corrosion are other factors to be considered. For steam, steel and iron are used, but steel is required for high pressure or temperature, and for very high temperatures, special alloy steel is necessary. For water, steel, iron, galvanized iron, brass and occasionally copper are used. Brass, wrought iron and Toncan iron are particularly indicated when corrosion is a consideration—likely in condensate-return systems. Copper-bearing steel and wrought iron have been found to be good materials for brine piping. Refrigeration piping material requires special consideration. Brass or copper bearing pipe and valve trim should not be used with ammonia. These materials should be used with caution for sulphur dioxide and only when it is certain no moisture will be in the system.



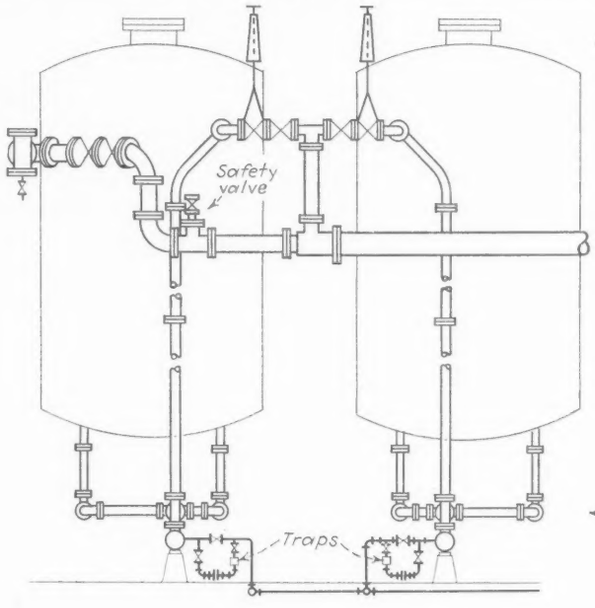


Fig.11-Steam piping to pulp digesters. Note convenient valve arrangement and trap at bottom of riser

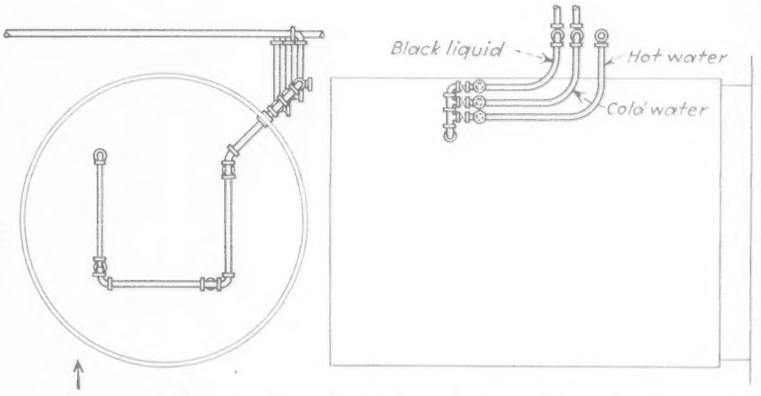


Fig.12-Piping hot and cold water and black liquor to blow pits in a soda-pulp mill

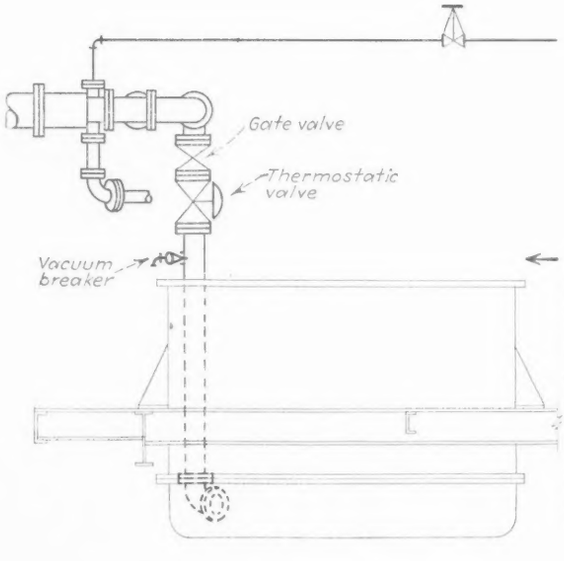


Fig.10-Steam piping to a sugar-melting pan. Steam admitted directly into the sugar, hence there is no drain piping. Note check valve to break vacuum formed when steam is shut off, so preventing sugar from being drawn into the piping

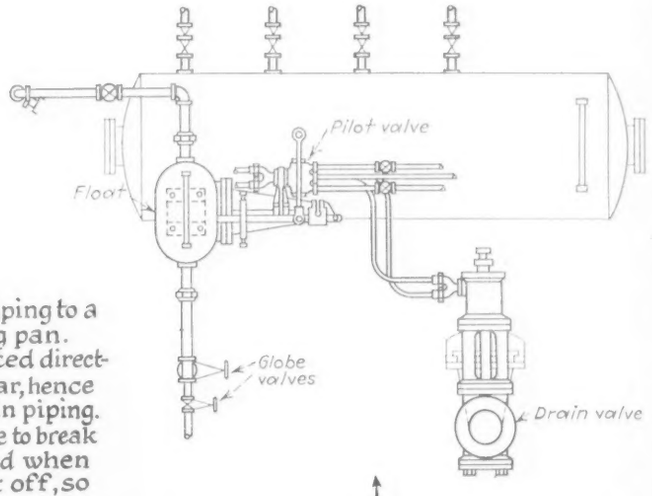


Fig.13-Method of handling condensate from vacuum pan shown in Fig.13. Condensate is drained from the receiver through a pilot-operated float valve and discharged to a second receiver of lower pressure. Flash is vented to a low-pressure steam header

2. RECORDS OF SERVICE CONSUMPTION

BOTH the process engineer and the power engineer have a stake in eliminating wasteful application of power services to process, and in avoiding the waste of services through improper operation of the processes. All experience shows that metering is the first step toward avoiding these wastes.

Service metering, in general, has several functions. 1. It makes possible correct costing of products and by-products. 2. It places responsibility for waste on the men in charge of wasteful operations and departments and thus creates a positive incentive to save. 3. Even conscientious men who need no incentive (if there are such) need meter data on the amount and location of service wastes before they can correct conditions.

It is well to get everybody from the president down thinking in terms of power services consumed per ton of ultimate product. Where the factory makes but a single product this is easy, involving only a single master meter for each service. Such a summary is of practical value out of all proportion to its cost, showing instantly whether the given plant is doing better or worse than others in the same industry, or better or worse than in previous months. Excess consumption of any service is a red flag calling for immediate action and often leading directly to thousands of dollars saved.

The many saving possibilities of such comparison have been extensively utilized by certain large corporations controlling several factories making similar products. Frequently they use a standard report form for all the plants, provide for top supervision of the reports and encourage the managers and power engineers of each plant to compare their results with those of the other plants. This has also served as a basis for incentives, of course with allowances made for variations in equipment.

Page 673 gives some typical figures on such unit service consumptions for various processes. The surveys on which these are based were not extensive enough to give assurance that the data represent either "average" or "first-class" performance. In fact, varying conditions warrant considerable variation from any general "standard." The tabulation should, however, be of interest for a preliminary check-up, since it includes figures on a wide variety of products and includes many large industrials presumably avoiding waste wherever possible. In cases where several reports on manufacture on a given product were received, figures have been averaged.

These averages may well serve as a basis for a plant engineer's contention that costs are too high due to obsolete equipment. Dollars talk louder than any amount of reasoning, and if an engineer can show that his figures are away out of line with these and can show what elements are causing the discrepancy, he may obtain results. It is at least worth trying.

Taking it for granted that all well managed process plants will keep over-all records of unit consumptions, the question arises as to how far it is worth while to break down such records. Fine breakdown is not so difficult from the accounting angle as it is costly from the angle of meter installation. Obviously it is not commercially practicable to meter every service to every process unit. In most cases it will pay to establish a breakdown by principal departments or principal groups of equipment, and meter to each such services as are used in substantial quantities. Minor services may be lumped and their costs distributed with the overhead.

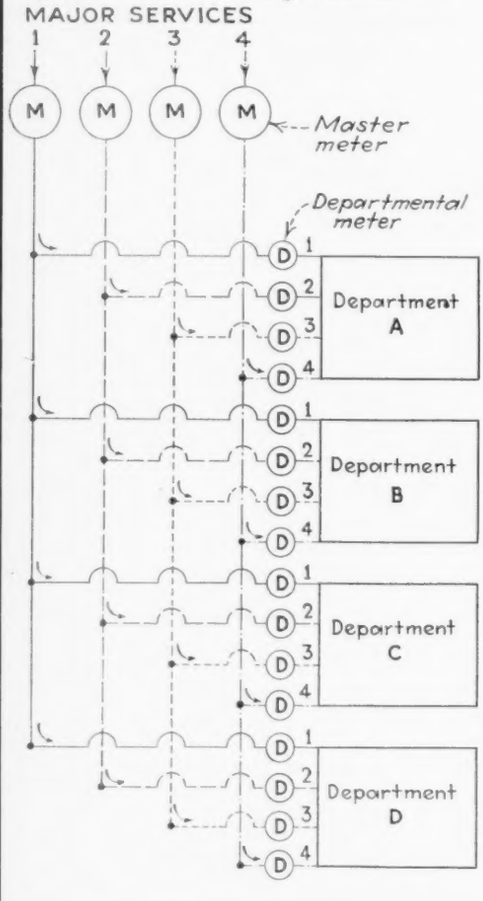
In many cases, portable meters and instruments (or meters and instruments with switching connections) may be used for periodic tests of individual units.

The accompanying chart and accounting form are to be considered together. They apply to a plant in which there are four departments and four major services. Other services are assumed to be used in quantities too small to justify separate metering.

The chart shows a departmental meter on each service to each department, 16 in all. Their readings give service distribution and also a check on the master meters.

This form does not show credits for returned condensate, partially cold or hot water, etc. If departments are being charged for the services they receive, they must likewise be credited for the services they return. It is manifestly unfair to charge two departments equally for steam used if one is returning all condensate and the other is using it all in process. The same reasoning holds true for other services.

Fig.1-Metering diagram for plant of 4 departments, with 4 major services



SERVICE DISTRIBUTION **Fig.2-Service-distribution accounting form**

for month of _____ Product units produced _____

Department	Service 1			Service 2			Service 3			Service 4			Misc. Service Total # *	All Services Total #
	Units Consumed	# Per Service Unit	Total #	Units Consumed	# Per Service Unit	Total #	Unit Consumed	# Per Service Unit	Total #	Units Consumed	# Per Service Unit	Total #		
A														
B														
C														
D														
Total for all depts.														
Total per unit of product														

(* Prorated to departments on arbitrary basis)

3. POWER SERVICE USE DATA

POWER, water, steam, refrigeration, and compressed air are used in various quantities by industry. It has seemed that consumption of these services per unit of production in many different industries would be of interest to many, particularly to consulting engineers and plant superintendents who may compare their consumption data with those given in the table below.

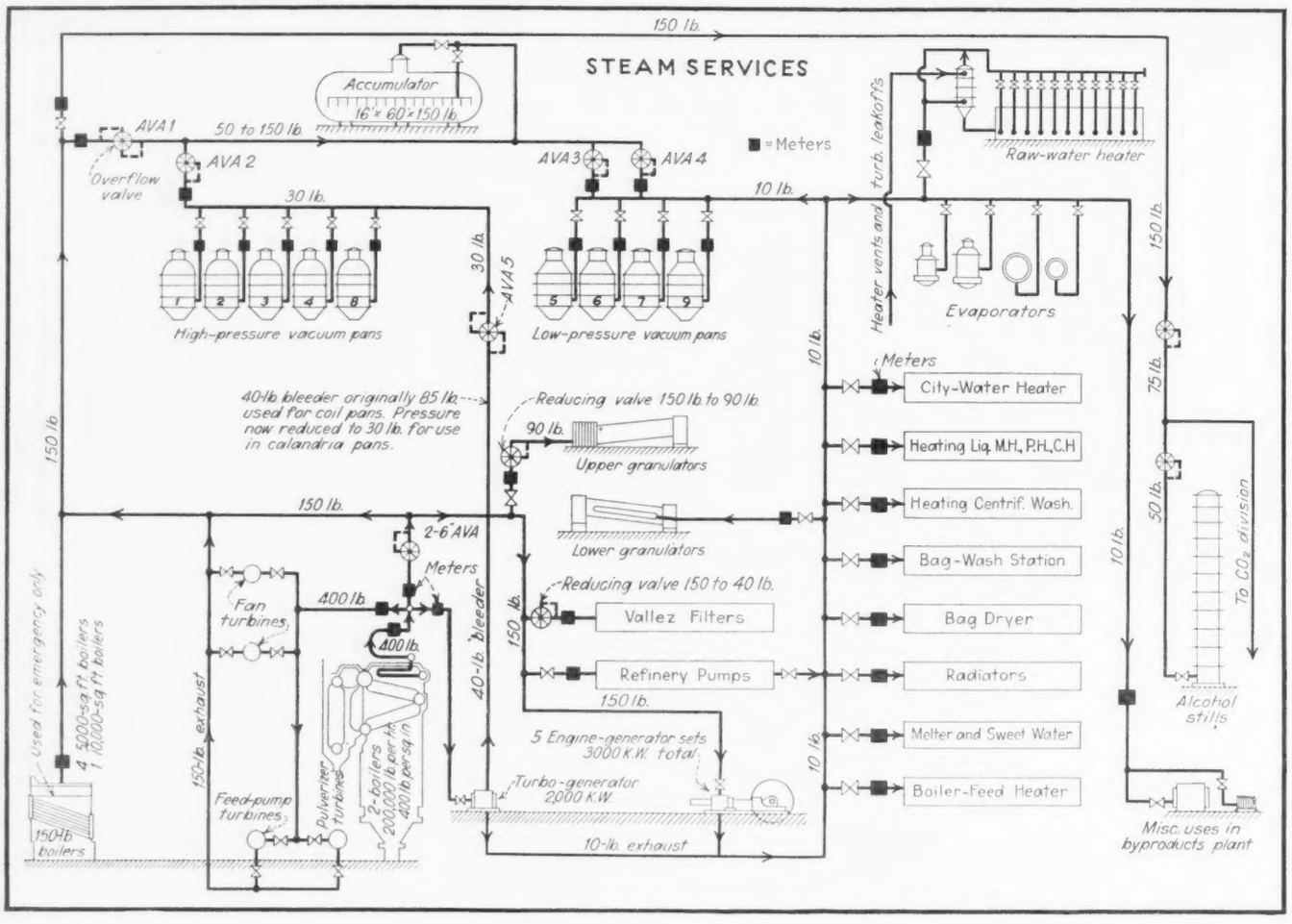
The data have been collected from many sources, some as a result of a questionnaire sent directly to industrial plants, some from *Chemical & Metallurgical Engineering, Food Industries, Textile World* and *Coal Age*. In many cases, data available have been incomplete, and where consumption figures of steam, water, refrigeration, compressed air, etc., are not given, it should not be inferred that these are not used.

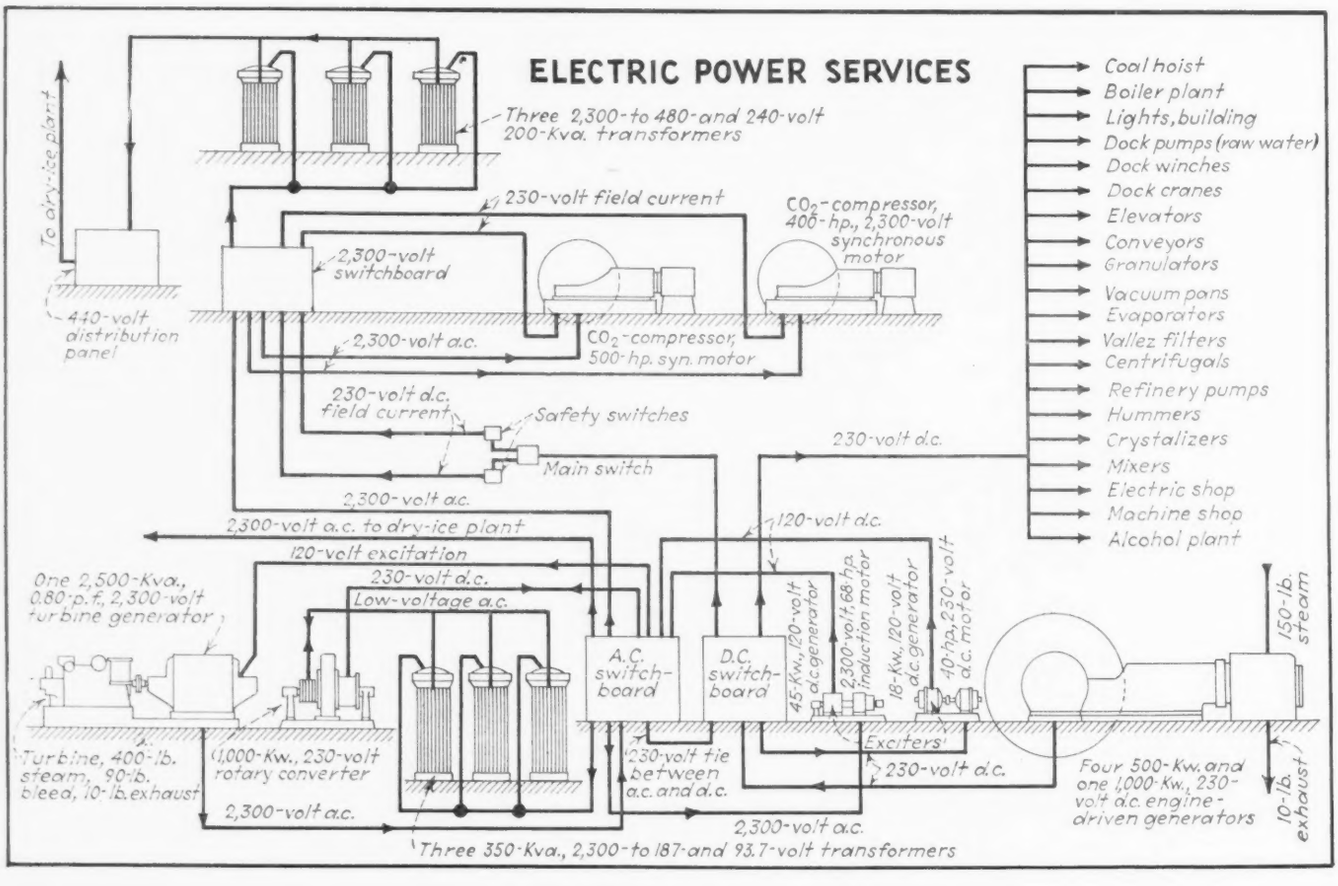
As may be expected, the consumption of power services per unit of product varies considerably among plants making the same product. Some of the data represent average consumption in several plants, others are from one plant only.

From returns to the questionnaire it became evident that many plants merely metered the total amount of power, steam and water used, and did not have a record of the distribution of these services to different departments. Thus, when the manufacturing operation produced several products it was impossible to give consumption figures for any one. That this condition exists is not surprising, but it is difficult to see just how accurate cost accounting can be accomplished without knowing the consumption of these services per unit of product. The relatively few figures available on the consumption of compressed air is interpreted to mean that this service is seldom metered. On the other hand, the same conclusion, though it is likely true, cannot be drawn in the case of refrigeration, as most of the industries listed do not use refrigeration.

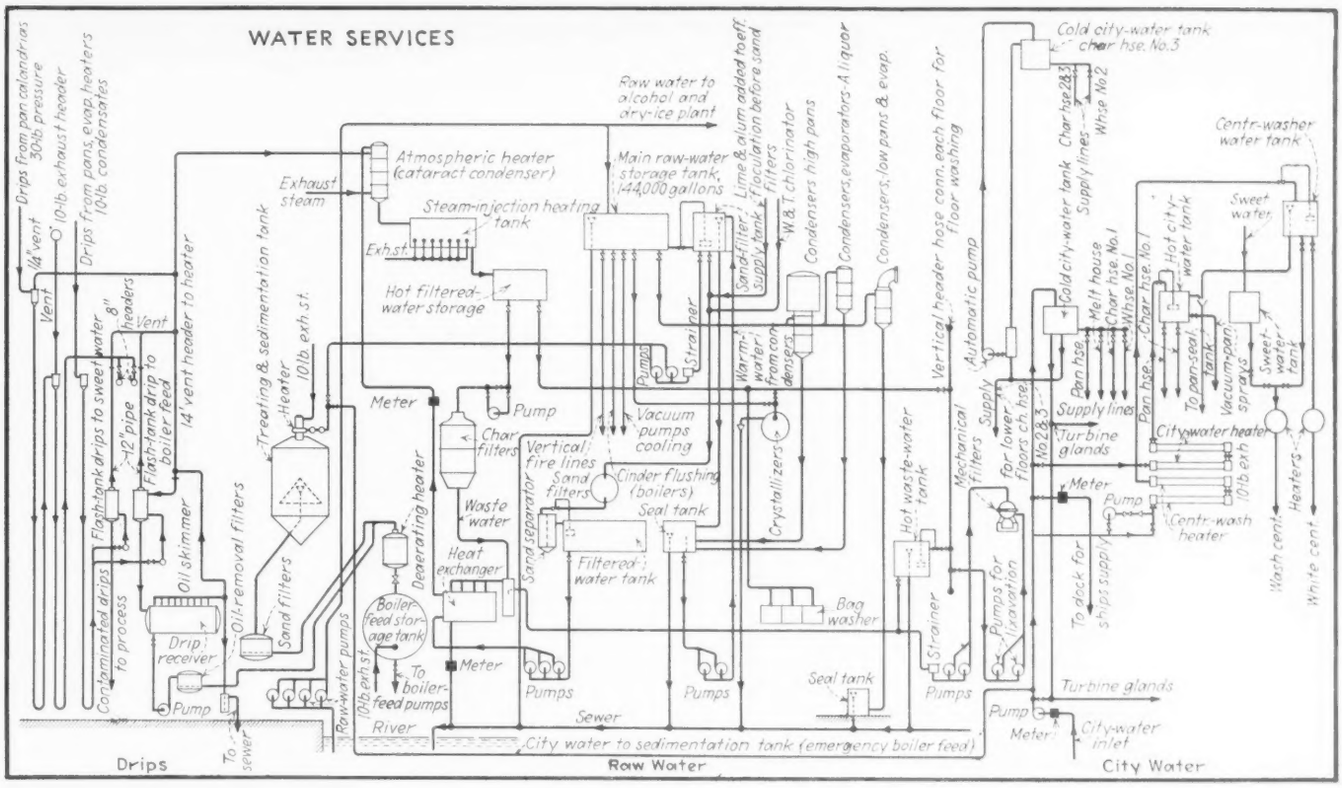
Data of this kind are relatively scarce, and *Power* will welcome similar information on industries not included here.

	Kw. Hr.	*Steam, lb.*	*Water, gal.*	*Refrig., tons*	*Cooling Water, gal.*	*Compressed Air, cu. ft.*
Acetic acid (from carbide), per ton	492	7,300				
Acetic acid (from pyroligqueous liquor), per ton	25	70,000	240,000			
Industrial alcohol, per gal	0.11	40	10	.....	42	
Alumina (Bayer process), per ton	180	15,000	6,300			
Carbon dioxide, per ton solid CO	65	15,000				
Casein, per 100 lb	12	1,200	var.			
Caustic soda (electrolitic), per ton 76%	2,500	20,000	.....	0.9		
Caustic soda (lime-soda), per ton 11%	18	2,700	2,200			
Glycerine, per ton	10	8,000				
Hydrochloric acid (salt process), per ton, 20 deg. acid	90	2,900				
Lactose (milk sugar), per 100 lb	17	5,000	10,000			
Magnesium carbonate, per ton	300	18,000	19,500			
Phosphoric acid (blast furnace), per ton	4	.....	75,000	.....	.....	450,000
Silicon carbide, per ton	7,000					
Sodium silicate, 40 deg. be., per ton	21.6	1,040	160	5,000 cu. ft. gas		
Liquid sulphur dioxide, per 100 lb	0.2	34	900			
Sulphuric acid (chamber process), per ton	18	94	3,000	.....	.....	198
Sulphuric acid (contact process), per ton	33	28	4,600	.....	.....	144
Trisodium phosphate, per ton	80	150				
Portland cement, per ton	90	.....	750	100 lb. coal		
Soda pulp, per ton, dry	250	13,000				
Sulphite pulp, per ton, dry	410	7,500				
Natural gasoline, per 10,000 gal	20	60,000	200,000			
Rayon (Viscose), per lb. of yarn	3	70	100	0.2		
Rayon (cupra-ammonium), per lb. 11% moisture	1.4	45–80	32–40			
Laundry soap, per ton	.....	4,000	230			
Rockwool, per ton	40	3,000	.....	.....	4,000	
Dyeing and finishing cotton fabric, per lb	.94	28	25–40			
Weaving army cotton check, per lb	1.28					
Weaving cotton print cloth, per lb	1.79					
Weaving surgical gauze, per lb	1.63					
Weaving narrow sheeting, per lb	1.75	12	2	.....	.....	200
Weaving broadcloth, per lb	1.93					
Weaving 60/1 combed warp yarn, per lb	2.40					
Weaving lawn, per lb	4.35					
Paper, per ton	10.8	390				
Pleasure cars and trucks	2.7	2,800	10,000	.....	.....	23,000
Pig iron, per g. ton	2.493	1,844	6,411			
Coke, per ton	10.109	563	2,726			
Pulp and paper, per lb	0.35	6.0	22			
Bleach, dye, print and finish cotton fabric, per 1,000 yd	62.7	8,325	6.29			
Paper (tissue and towels), per ton	500	10,000	16,000			
Tanning (glazed kid), per doz. skins	93	340	400			
Brass rolling (ammunition), per lb	0.595	7.7	15.33	.....	.....	2.92
Flour, per bbl	7	1	6.9			
Butter and condensed buttermilk, per lb	0.057	1.5	10			
Wool scouring and carbonizing, per lb	0.12	7.2	2			
Hard-rubber products, per lb	1.3	34	18	.....	.....	36
Tires and tubes, per lb	0.34	7.02	10.2	.....	.....	16.2
Drying apples, per ton of fresh fruit	41.3	18.5 gal. fuel				
Drying grapes, per ton of fresh fruit	27.2	23.6 gal. fuel				
Drying prunes, per ton of fresh fruit	32	20.2 gal. fuel				
Sugar refining, per 100 lb	3.5	260	56	.....	557	
Hotel, per occupied room	3.5	.....	16.1	0.04 lb. coal		
Vacuum cleaners, per vacuum cleaner	28.1	2.40	.....	.....	.....	1925
Mining Coal, per ton	5.7					
Cleaning Coal, (Rheolaveur process) per ton	.....	.....	840			


STEAM SERVICES
150 lb.
Accumulator
16" × 60" × 150 lb.
AVA 1
50 to 150 lb.
AVA 2
Overflow valve
30 lb.
AVA 3
AVA 4
10 lb.
■ = Meters
Raw-water heater
Heater vents and turb. leakoff's
Evaporators
High-pressure vacuum pans
AVA 5
Low-pressure vacuum pans
40-lb. bleeder originally 85 lb. used for coil pans. Pressure now reduced to 30 lb. for use in calandria pans.
Reducing valve 150 lb. to 90 lb.
90 lb.
Upper granulators
Lower granulators
2-6 AVA
Meters
Reducing valve 150 to 40 lb.
Fan turbines
400 lb.
Vallez Filters
Refinery Pumps
Feed-pump turbines
Pulverizer turbines
2-boilers 200,000 lb. per hr. 400 lb. per sq. in.
5 Engine-generator sets 3000 K.W. total
Turbo-generator 2000 K.W.
10-lb. exhaust
Meters
City-Water Heater
Heating Liq. M.H., P.H., C.H.
Heating Centrif. Wash.
Bag-Wash Station
Bag Dryer
Radiators
Melter and Sweet Water
Boiler-Feed Heater
75 lb.
50 lb.
To CO2 division
Alcohol stills
Misc. uses in byproducts plant
Used for emergency only
4 5000-sq. ft. boilers
1 10,000-sq. ft. boiler
150-lb. exhaust
150-lb. boilers


ELECTRIC POWER SERVICES
To dry-ice plant
Three 2,300- to 480- and 240-volt 200-Kva. transformers
230-volt field current
CO2-compressor, 400-hp., 2,300-volt synchronous motor
2,300-volt switchboard
440-volt distribution panel
2,300-volt a.c.
CO2-compressor, 500-hp. syn. motor
230-volt d.c. field current
Safety switches
Main switch
230-volt d.c.
2,300-volt a.c.
2,300-volt a.c. to dry-ice plant
120-volt d.c.
120-volt excitation
230-volt d.c.
Low-voltage a.c.
One 2,500-Kva., 0.80 p.f., 2,300-volt turbine generator
A.C. switch-board
D.C. switch-board
45-Kw., 120-volt a.c. generator
2,300-volt, 68-hp. induction motor
18-Kw., 120-volt a.c. generator
10-hp., 230-volt a.c. motor
150-lb. steam
Exciters
230-volt d.c.
Turbine, 400-lb. steam, 90-lb. bleed, 10-lb. exhaust
1,000-Kw., 230-volt rotary converter
230-volt tie between a.c. and d.c.
Four 500-Kw. and one 1,000-Kw., 230-volt a.c. engine-driven generators
10-lb. exhaust
2,300-volt a.c.
2,300-volt a.c.
Three 350-Kva., 2,300- to 187- and 93.7-volt transformers
Coal hoist
Boiler plant
Lights, building
Dock pumps (raw water)
Dock winches
Dock cranes
Elevators
Conveyors
Granulators
Vacuum pans
Evaporators
Vallez filters
Centrifugals
Refinery pumps
Hummers
Crystalizers
Mixers
Electric shop
Machine shop
Alcohol plant

A LARGE SUGAR PLANT



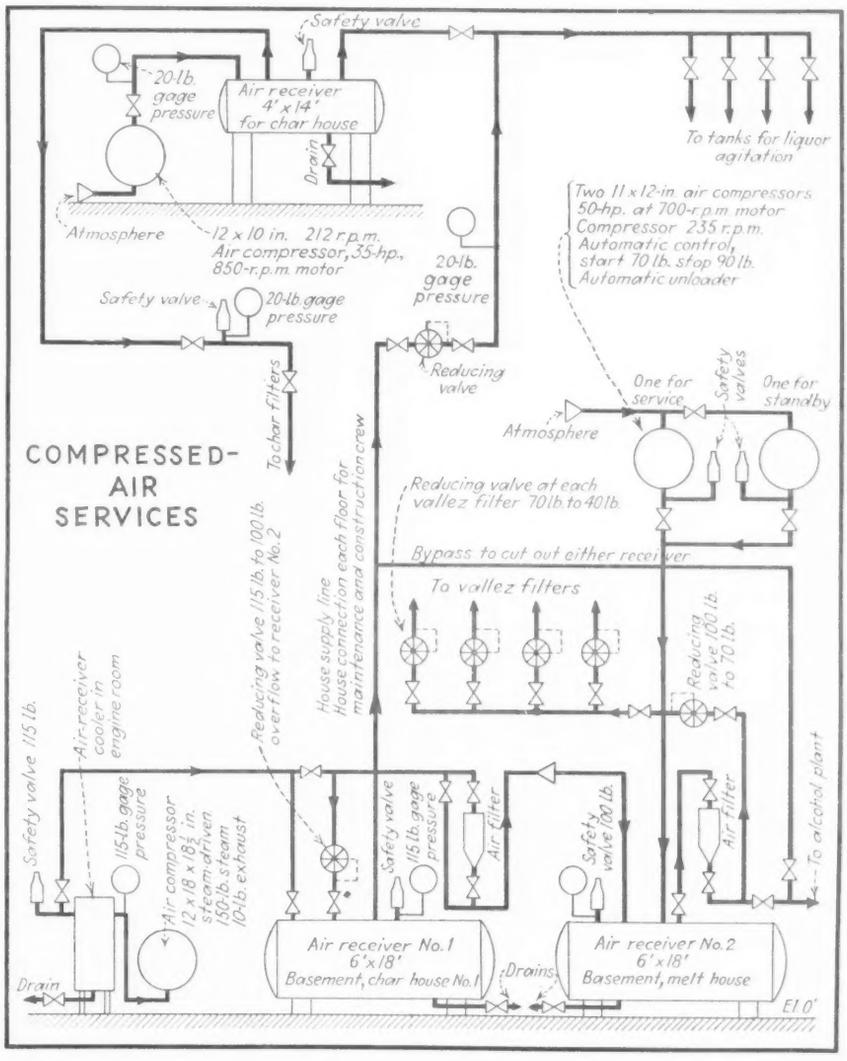
● As stated earlier, in process work only unit operations are similar. These two pages show how steam, electric power, water and compressed air—typical services—are supplied to the manufacturing processes of a large sugar refinery—a typical process. In this plant, steam is normally supplied at 400 lb. per sq. in. for power generation and process. A 2,000-kw. turbine is bled at 40 lb. and exhausts at 10 lb. for process. Process steam is also supplied at 150 lb., 90, 40, 30 and 10 lb. through reducing valves. Five engines driving d.c. generators take steam at 150 lb. and exhaust at 10 lb. All power is generated by non-condensing units totaling 5,000 kw. Steam at all services is metered as in the steam diagram.

Electric power is generated at 2,300 volts a.c. and 230 volts d.c. as shown by the Electric Power Service diagram. A 1,000-kw. rotary converter forms a tie between the two systems.

As indicated in the Water Service diagram the water-supply system is very extensive. A large part of the water required, 20,000,000 gal. per day, is pumped from the river and delivered to a 144,000-gal. tank at elevation 115 ft. It is used cold, treated, filtered, or heated according to process and boiler-plant requirements. To meet process needs, 15 pumps are used for various purposes, in addition to the four main supply pumps. About 8,000,000 gal. of water per month is purchased from the city and is used cold or hot for washing sugar and for certain other special processes.

Compressed air is supplied by four compressors at 115, 80 and 20 lb. All three systems are tied together through reducing valves. For the vallez filters, the 115-lb. air is first reduced to 70 lb. and then to 40 lb. through reducing valves.

Layouts and data were provided by Dan Gutleben, engineer, Pennsylvania Sugar Co., Philadelphia, Pa., and his assistant, Newton Smith.


COMPRESSED-AIR SERVICES
Safety valve
20-lb. gage pressure
Air receiver 4' x 14' for char house
Drain
To tanks for liquor agitation
Two 11 x 12-in. air compressors
50-hp. at 700-r.p.m. motor
Compressor 235 r.p.m.
Automatic control, start 70 lb. stop 90 lb.
Automatic unloader
Atmosphere
12 x 10 in. 212 r.p.m. Air compressor, 35-hp., 850-r.p.m. motor
20-lb. gage pressure
Safety valve
20-lb. gage pressure
Reducing valve
To char filters
One for service
Safety valves
One for standby
Atmosphere
Reducing valve at each vallez filter 70 lb. to 40 lb.
Bypass to cut out either receiver
To vallez filters
Reducing valve 100 lb. to 70 lb.
Reducing valve 115 lb. to 100 lb. overflow to receiver No. 2
House supply line
House connection each floor for maintenance and construction crew
Air-receiver cooler in engine room
Safety valve 115 lb.
115-lb. gage pressure
Air compressor 12 x 18 x 18 in. steam-driven 150-lb. steam 10-lb. exhaust
Safety valve
115 lb. gage pressure
Air filter
Safety valve 100 lb.
Air filter
To alcohol plant
Air receiver No. 1 6' x 18' Basement, char house No. 1
Drains
Air receiver No. 2 6' x 18' Basement, melt house
Drain
El 0'

ROUND-UP

AS WE COME to the end of this 36-page section, it seems well to remind readers again, as we did on page 641, that this process information is presented as an aid to the power engineer in the process plant—to help him cooperate more effectively with the process engineer.

The power engineer is responsible for the generation and transmission of the power services. He is also vitally concerned with the elimination of waste in their application, because excessive consumption will ruin his over-all power-cost record even though his unit costs show expert management of generation. And he knows that these application savings must be made without sacrificing capacity of process units or quality of product.

In every respect these concerns of the power engineer are identical with those of the process engineer. The process engineer merely switches the emphasis. With him, unit capacity and product quality get first attention. Yet he, too, must ultimately stand or fall on costs, and his processing costs are largely power-service costs. He has a direct stake in the efficient production of the power services he uses and, of course, in their correct and economical application.

This situation calls for active and intelligent cooperation. The process engineer must have a general understanding of the power services and their unit costs. The power engineer must know enough about the process to hook the services in correctly—right wiring and switches, right piping, meters, controls, valves, traps. He must consider how splashing and drips from process may affect his service application equipment, including heat insulation. He must so place his piping and equipment that it will not interfere with process or operators.

It is equally important that he be able to suggest savings through substitution of services—exhaust steam instead of high-pressure, paddle stirring in place of air agitation (or the reverse), alternative mechanical or electrical drives, and so on.

Since the jobs of power engineer and process engineer overlap at the point of service application, neither can work effectively without the help of the other. The conclusion is inevitable that the power engineer must study process requirements. Much of his application knowledge must come from first-hand experience in the plant, but we hope that this condensed handbook of service-to-process fundamentals will be helpful and that the tables and charts will be found convenient for ready reference and rapid computation.

PHILIP W. SWAIN
Editor of *Power*

LIST OF SPECIAL SECTIONS
Published in *Power*, to Date

SUBJECT	NO. OF PAGES	DATE
Piping	13	Feb., 1935
Maintenance	32	April, 1935
Diesel Data	19	June, 1935
Refractories and Furnaces	20	Sept., 1935
		Mar., 1936
Boilers	20	Dec., 1935
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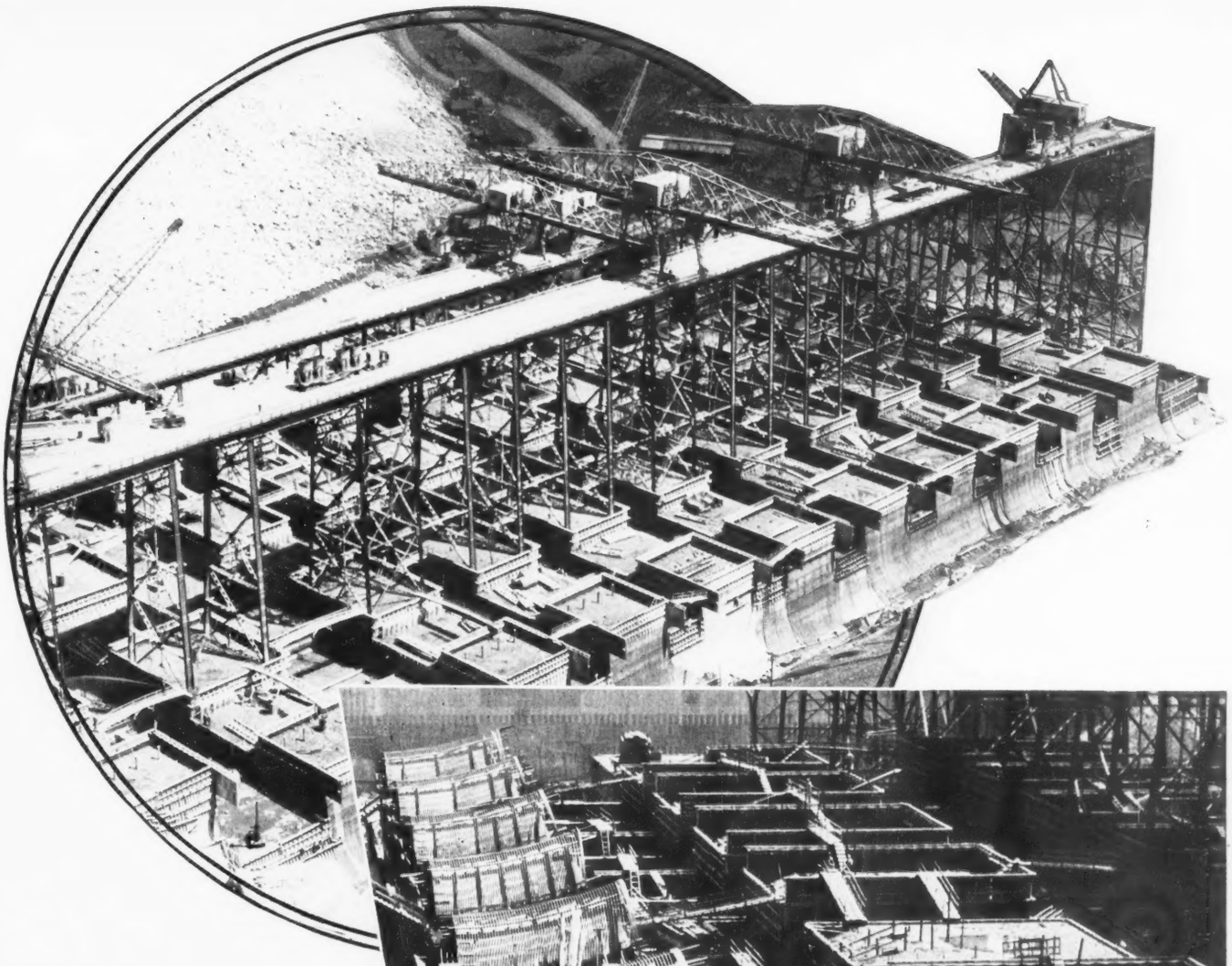
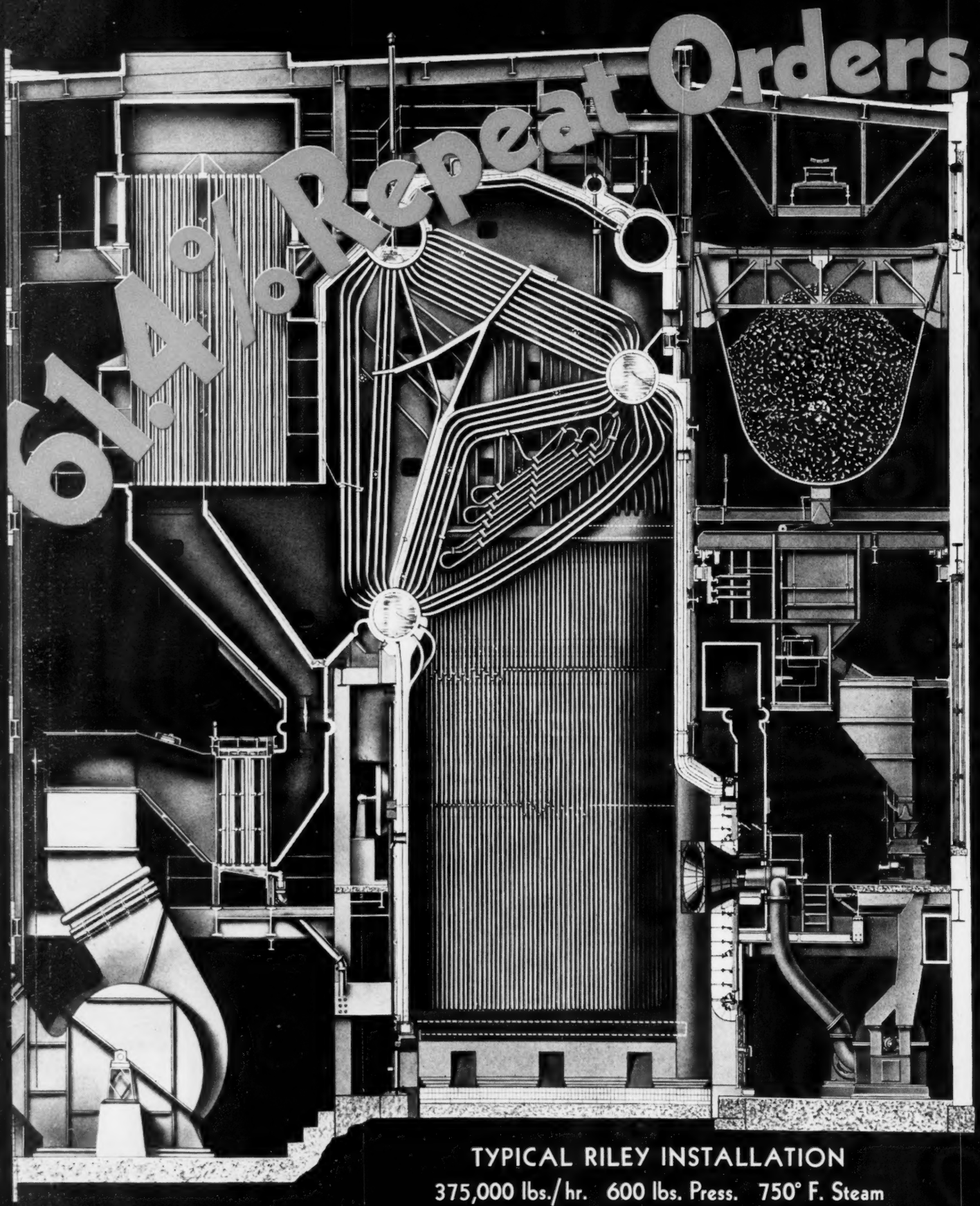


GRAND COULEE

. . . . world's largest dam and power plant, being built at Grand Coulee on the Columbia River

Some idea of the massiveness of Grand Coulee dam is gained by the upper view looking down on part of the foundation now under construction. At right are shown the forms and reinforcing steel for penstocks for one of the two power houses; each to have nine 140,000-hp. units, aggregating 2,500,000-hp. The dam, when completed, will be 4,100 ft. long, 540 ft. high, contain 10,000,000 cu. yd. of concrete, and will form a reservoir of 9,610,000 acre-feet. Present plans call for constructing the foundation at a cost of $63,000,000.



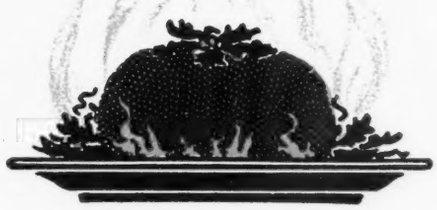
TYPICAL RILEY INSTALLATION
375,000 lbs./hr. 600 lbs. Press. 750° F. Steam

RILEY STOKER CORPORATION

COMPLETE STEAM GENERATING UNITS

BOILERS • PULVERIZERS • BURNERS • STOKERS • SUPERHEATERS • AIR HEATERS
ECONOMIZERS • WATER COOLED FURNACES • STEEL-CLAD SETTINGS • FLUE GAS SCRUBBERS

the best Proof of the Pudding



That 61.4% of all orders received in 1936 by Riley were repeat orders from satisfied users is the best proof of the outstanding performance of Riley equipment.

Users of equipment know best from actual experience what can be expected of steam generating and fuel burning equipment. When they install new equipment of the same manufacture they do so because of satisfactory performance of the former installation.

It is because of the excellent results, complete satisfaction, absolute reliability and general engineering excellence of recent Riley installations that there has been such a very decided swing to Riley steam generating equipment. That is why Riley sales to date in 1936 are more than double 1929 sales.

In justice to yourself be sure to visit and thoroughly investigate some recent Riley installations when considering new or additional steam generating and fuel burning equipment.

FACTS

61.4% Repeat Orders

Of all Riley orders in 1936, 61.4% are repeat orders from satisfied users.

1936 Sales double 1929

The very decided swing to Riley steam generating equipment has carried sales in 1936 to more than double 1929 sales.

Outstanding Installations Riley Equipped

A very large percentage of the country's recent outstanding boiler installations are Riley installations.

***The* SWING *continues to* RILEY**

A PARTIAL LIST OF RECENT BUYERS OF RILEY EQUIPMENT

Lynn Gas & Electric Co.
North Dakota Power & Light Co.
Fort Bend Utilities
Upper Mich. Power & Light Co.
Guide Lamp Company
General Motors Corporation
Standard Oil of California
Bemis Bros. Bag
West Virginia Pulp and Paper
Socony Vacuum Oil Co.
Carbide & Carbon Chemicals
Owens-Illinois Glass
Celanese Corp. of America
American Laundry Machinery
Crompton & Knowles
Beechnut Packing
Container Corporation
Titanium Pigment Co.
Crystal Tissue Paper Co.
Imperial Paper & Color Co.
University of Minnesota
Arnold Print Works
Continental Distilling
Kalamazoo Vegetable Parchment Co.
Forstmann Woolen Co.
General Aniline Works
Pet Milk Co.
McAndrews & Forbes Co.

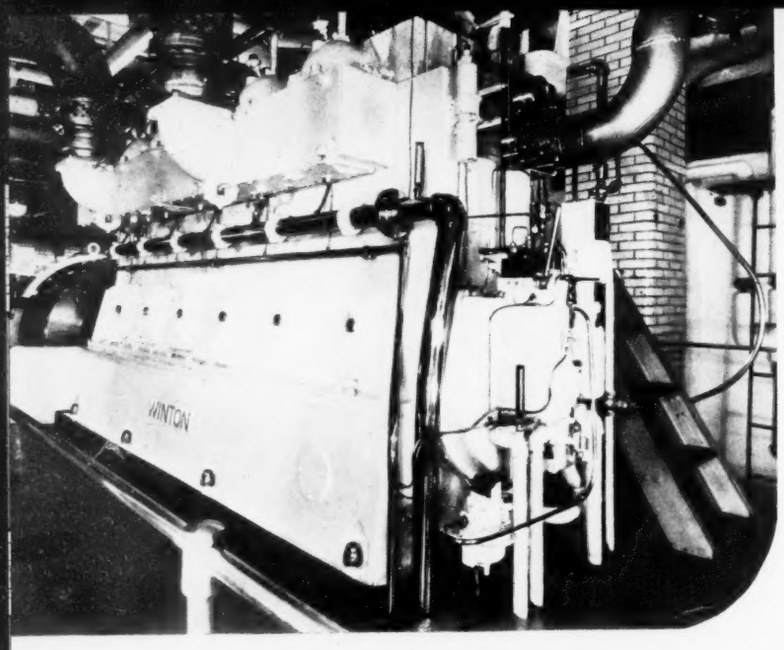
RILEY

STOKER CORPORATION
WORCESTER - MASSACHUSETTS

COMPLETE STEAM GENERATING UNITS

BOILERS - SUPERHEATERS - AIR HEATERS - ECONOMIZERS - PULVERIZERS - BURNERS - STOKERS
WATER-COOLED FURNACES - STEEL CLAD SETTINGS

BOSTON NEW YORK PHILADELPHIA PITTSBURGH BUFFALO CLEVELAND DETROIT TACOMA
ST. LOUIS CINCINNATI HOUSTON CHICAGO ST. PAUL KANSAS CITY LOS ANGELES ATLANTA



Control end of the 525-hp. diesel in the Singer Building showing twin exhaust outlets and their interlocked butterfly valves, governor, and welded intake piping. Note white enamel and chromium plating

18 Months with Diesel

A year and a half ago, Norman King added a 525-hp. diesel to his Singer Building steam plant. His men were all steam engineers without diesel experience. Here's how they installed and learned to operate the new unit, and some of the things they learned

By Norman M. King

Chief Engineer, Singer Bldg.

As told to E. J. TANGERMAN, Associate Editor, Power

ABOUT two years ago, we ordered a 6-cyl., 525-hp., Winton diesel direct-connected to a 350-kw. Diehl welded-frame generator and controlled by a Woodward governor. It was to be used to better our heat balance, in summer and over week-ends and holidays, and as a standby to replace utility breakdown. While we all knew what a diesel was, none of us had ever operated one, and several of the men had never seen one. At that time, I said that we didn't know anything about a diesel, but that in two years we would. Only a year and a half has elapsed, but we know plenty about our diesel already.

In February, 1935, when Winton was testing the engine, I went to the Cleveland plant, and every day from eight in the morning until five at night, I watched every test, asking all the questions I could think of. On March 21, 1935, the engine arrived in New York. My men assisted in uncrating, disassembly into pieces small enough to enter a 3½x9-ft. sidewalk grating, and carrying it—44 tons of it—to the foundation which we had ready for it where one of our old boilers had stood. We assembled it, piece by piece, with only a Winton construction engineer supervising. As assembly progressed, the men were encouraged to stay around after hours—with pay—to learn about the engine. Later on they all learned how to start it, stop it, check exhaust, water and oil temperatures, and do the other things that constitute operating a diesel.

Most of them knew all about automobile engines, so were familiar with the principles, and a good mechanic readily applies previous knowledge to a new job in hand. It speaks much for the powers of observation of these men when I say that we haven't had any real trouble with the engine since we started it. For five days in May a year ago, we ran the engine from 6 to 10 P.M. every evening, starting it, stopping it, getting out any lingering bugs in engine and auxiliaries. Then we decided it was right, and let the painters go to it.

In June it took load, and for the last year and a half has been taking it. How long have we run it? Well, three runs this summer were 53, 52 and 49 days, on 65% to over 100% load, 24 hours a day. At night the diesel carried building load alone and during the day it carried the lion's share—the steam plant only carrying enough to supply necessary heating steam from its exhaust. Believe it or not, for six months, I never opened the backpressure valve, just divided building load by adjusting the rheostats on the diesel and the steam engine to hold the diesel as near as possible to 95% load. For three months, through the summer, the diesel carried the building load alone 12 to 14 hours a day. By contrast, last winter for three weeks we didn't use the diesel at all—just started it up once in a while to see that it was all right. The reason? Outside temperature stayed below 17 above zero, so we needed all the exhaust steam we could get—plus live steam—to handle the heating load. Then the steam plant was cheapest, but when steam demand drops off, the diesel is cheapest.

Our heating season is seven months and two weeks long—only during three summer months do we actually waste any exhaust steam. We figure 34 lb. of steam per kw.-hr.—not bad for a 29-year old plant, but the diesel beats that hollow. Unfortunately I am not at liberty to quote exact figures at this time, but I can say that the diesel has paid back about a third of its cost in savings already. For the first 1,800,000 kw.-hr. generated by diesel, we averaged about 12.2 kw.-hr. per gal. of fuel oil, and are now averaging about 3,200 b.hp.-hr. per gal. of lubricating oil. I'll have more to say about that last figure later. Proportions between steam and diesel? In September of this year, we generated 155,750 kw.-hr. by diesel, 65,100 by steam. I expect the diesel to produce a third of our total output—in fact, charge it with a third of the time of my four engineers and four oilers. The engine doesn't take that much of their time during running periods, but when I shut it down for checkup, I put every available man on it until it is back in service, so the time balances up almost exactly.

Operation

Of course a diesel requires more handling than a steam engine—a lot more, but if you concede that, it is very easy to keep running. When it's running, the operators simply grease and oil every 8-hr. shift and make minor adjustments to bring exhaust tempera-

tures into line. We keep cylinder temperatures within 20 deg. of each other—in fact usually have at least four cylinders exactly alike. The engineer checks exhaust temperatures, water in and out temperatures, lubricating oil in and out temperatures on the hour (Bristol multi-point pyrometer), the oiler on the half hour, and both of them on every shift know how to stand and listen to the engine. You know, a good engineer can tell a lot about how well an engine is running by just listening to it. We blow indicator cocks every morning to clear them of carbon—connecting passages are small and long and once we had to drill them out because we failed to blow them often enough. Once per shift we oil the Sharples centrifuge and clean it. Otherwise, the engine runs continuously for about 1,200 hours before a shutdown for inspection.

When we shut down to pull pistons—which we do every six months—we expect to have the engine back on the line in three days. Tools are all laid out the night before. Every man knows what he is to do, and as soon as the engine goes down they begin to do it—marking each part and pipe with the appropriate cylinder number and lining them up along the wall. We tram the cylinders fore and aft—parallel with the shaft to you landlubbers—as well as across, using a jig to be sure we always tram in exactly the same places. This is of course immediately recorded and compared with previous trammings. Wear thus far totals 0.0035 in. on a side, or 0.007 in. on the diameter, pretty good for a 14-in. piston! The crankcase is drained and flushed out with kerosene, the water passages in the water-cooled heads cleaned, the water-side plates taken off and the water side of the liners looked at, and of course—the main job—the rings and valves are checked, cleaned, and replaced when necessary. When you consider that piston diameter is 14 in. and there are six rings per piston—a total of 36 to be fitted and checked—that in itself is a pretty good-sized job to finish in three days.

Piston-Ring Changes

The original ring arrangement was five compression rings above and a wiper on the skirt, but with that arrangement we only got about 2,000 b.hp.-hr. per gal. of lube. We added another wiper ring in place of No. 5 compression ring, and boosted lubricating-oil economy to 3,600 b.hp.-hr. per gal.—which is good oil economy. We later replaced all original rings with complete sets of American Hammered rings and have since gotten the same good economy figure with less wear and breakage.

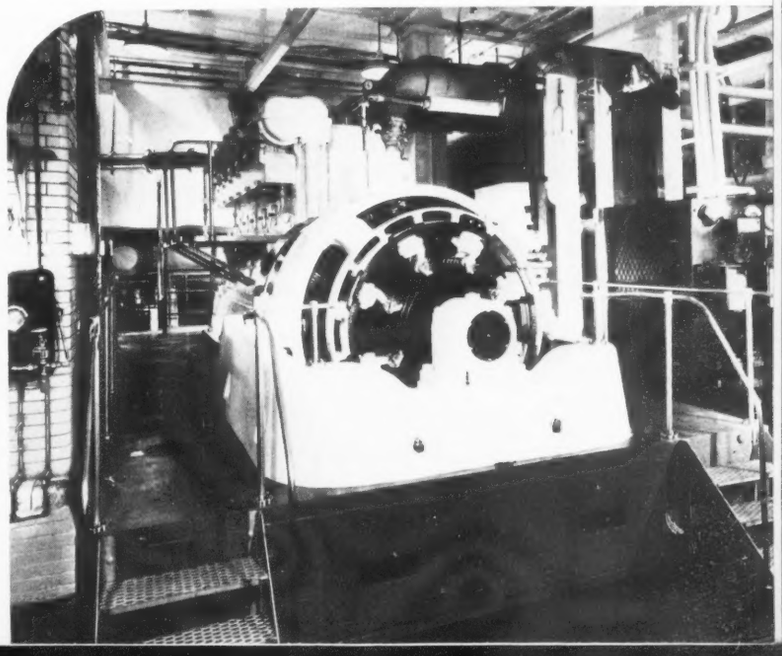
This last overhaul we also checked over the Binks cooling tower and cleaned the nozzles. Though it is installed next to the diesel in the basement, we have had no trouble with mist either in boiler room or stack. Stack temperatures are higher than water temperatures by far, so any mist that gets through the eliminators is promptly vaporized and carried well outside the stack—which goes up to the 14th floor. Our jacket-water loss runs about 6 cu.ft. per hr., with somewhere between 150 and 225 g.p.m. circulated. (A 150-g.p.m. Goulds pump recirculates, supplemented by a 75-g.p.m. Goulds pump from the cooling tower.) We hold water inlet and outlet temperatures within 7 to 10 deg. with the thermostatic-valve arrangement described in *Power* in June, 1935, pages 299-301, and are now treating with 16 oz. of Sand-Banum every two weeks. Jackets are as bright and clean as anybody could hope for.

What have we changed from the original arrangement? Well, the most important change was the piston rings. We modified the starting-air valve arrangement a little, put Alemite fittings on parts to be lubricated—even to the governor wedges—and changed the lubricating-oil cooler piping. We found that we had to provide for two conditions—summer and winter cooling. Originally, cold water from the cooling tower was mixed through the Taylor thermovalve with the hotter water recirculated from the engine, and the mixture passed through the Schutte & Koerting lube-oil cooler before it was returned to the engine. But in summer this allowed the oil to get too hot. Now we have repiped so that in summer we can pass the cooling-tower water through the lube-oil cooler first, then to the thermovalve. (In winter, we still use the original arrangement.) We hold jacket water at 125 inlet and 135 deg. outlet, lube oil at 137 to 145. (Before we repiped it used to go 15 deg. above that in summer.)

General comments? Well, recently, for some students, we timed starting of the diesel with a stopwatch. From standing idle to full speed and on the line too in just 35 seconds—we always keep lubricating oil to temperature with steam when the diesel is off the line, and always are assured of jacket water and lubricating oil because of piping arrangements which provide a "head" on both systems.

Our butterfly-valve arrangement on the twin exhaust piping (one to the Foster Wheeler feedwater heater) is working out all right. We provide feedwater at something above 264 deg. during the day, and as high as 300 deg. at night, depending of course upon engine load and amount of feedwater passed through. Normally we operate through the heater, opening up the direct-exhaust outlet only once a day or two, to prevent accumulation of carbon. Once in a while, toward the end of a run, we notice a little valve flutter, but a shot of kerosene fixes that.

Figures? At the moment I can't give you any more than I have already—but we have them to the last decimal place. We have meters and gages on everything, and keep records, so can work out costs accurately. Thus far, they're according to estimates.



Generator end, showing the spring-mounted, 44-ton foundation, the instrument panel, and arched, incased, generator leads. Boilers are in line on the other side of the columns which can just be seen at left

STAINLESS STEEL TRIM

AT NO

FOR ACCURACY

Properly designed, adjustable springs, carefully calibrated and tested under actual operating conditions.

FOR SENSITIVITY

Phosphor bronze diaphragm of special, exclusive beaded construction.

FOR SMOOTH ACTION

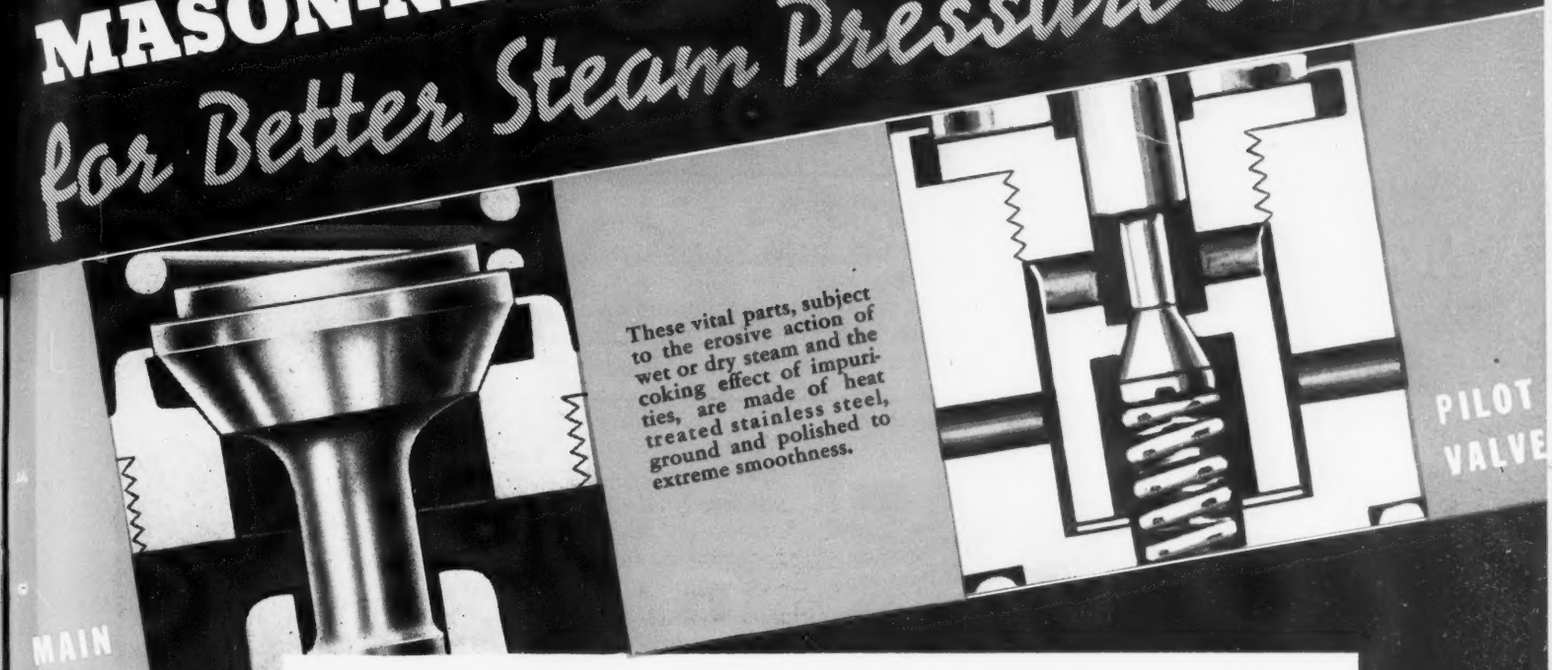
Ground and polished valves, piston and cylinder. Precision workmanship throughout.

MASON-NEILAN REGULATOR COMPANY

EXTRA COST...

in the New MASON-NEILAN REDUCING VALVE

for Better Steam Pressure Control


MAIN VALVE
These vital parts, subject to the erosive action of wet or dry steam and the coking effect of impurities, are made of heat treated stainless steel, ground and polished to extreme smoothness.
PILOT VALVE

Mason-Neilan, recognizing the advantages of stainless steel trim, now offers a line of steam pressure reducing valves with *heat treated* stainless steel trim *at no extra cost.*

Pilot and main valves are made of special high-carbon, stainless steel, heat treated to 500 Brinnell hardness. Valve seats are machined from "18-8" stainless steel of 150 Brinnell hardness.

Approximately 90% of all troubles—wire drawing, steam cutting and valve sticking—usually experienced with steam pressure reducing valves, are thus eliminated; the life of the valve increased; and maintenance costs reduced as much as two-thirds.

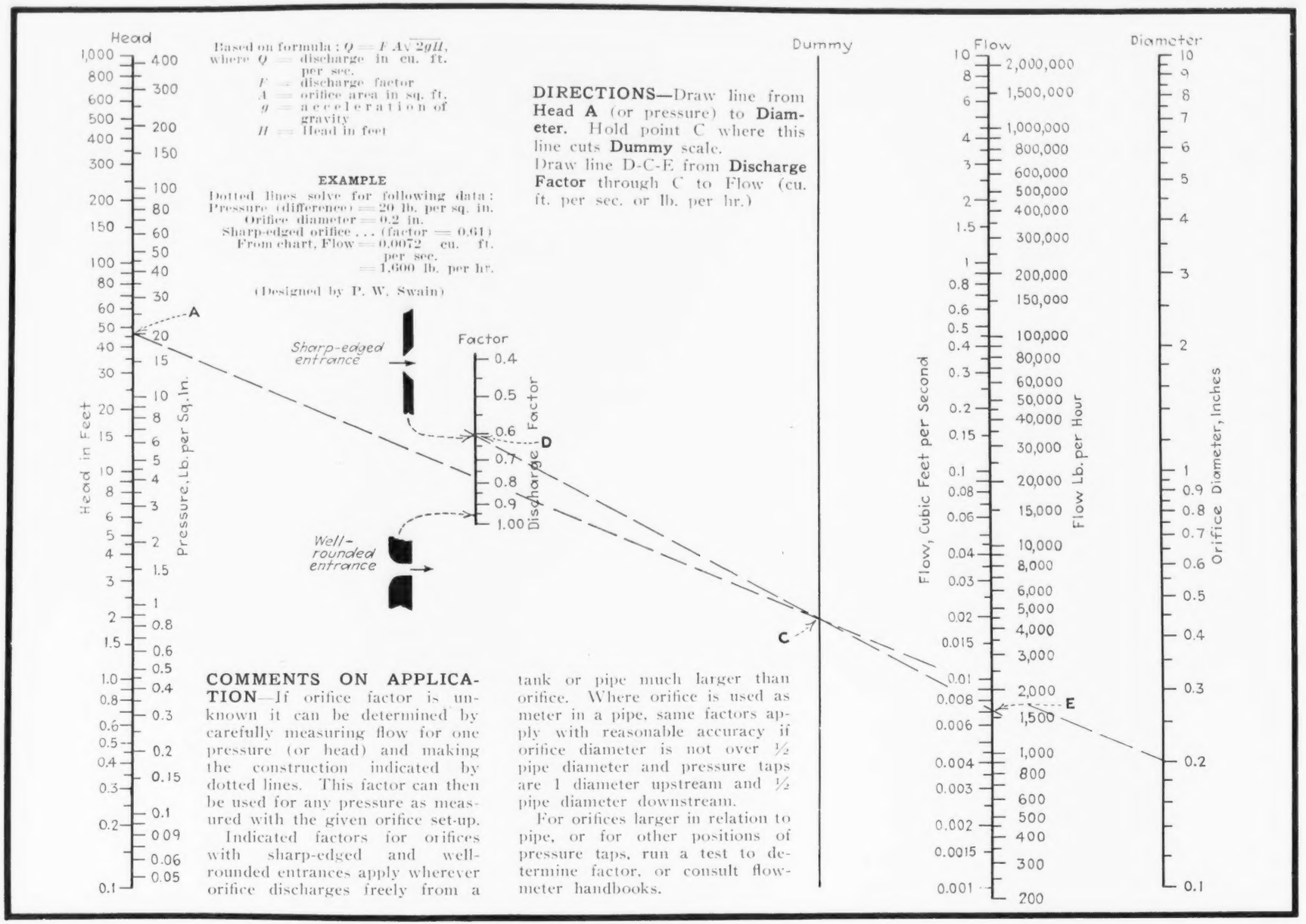
For better steam pressure control at lower cost, specify Mason-Neilan Reducing Valves—one quality, the best—at one price.

MASONEILAN

1186 ADAMS STREET, BOSTON, MASS.

© POWER

Flow of Water Through Orifices



Based on formula: $Q = F A \sqrt{2gH}$, where Q = discharge in cu. ft. per sec., F = discharge factor, A = orifice area in sq. ft., g = acceleration of gravity, H = Head in feet

EXAMPLE

Dotted lines solve for following data:
Pressure (difference) = 20 lb. per sq. in.
Orifice diameter = 0.2 in.
Sharp-edged orifice . . . (factor = 0.61)
From chart, Flow = 0.0072 cu. ft. per sec.
= 1,600 lb. per hr.

(Designed by P. W. Swain)

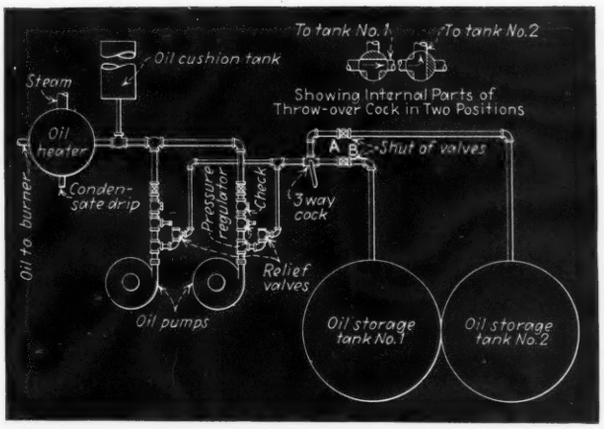
DIRECTIONS—Draw line from **Head A** (or pressure) to **Diameter.** Hold point C where this line cuts **Dummy** scale.
Draw line D-C-E from **Discharge Factor** through C to Flow (cu. ft. per sec. or lb. per hr.)

COMMENTS ON APPLICATION—If orifice factor is unknown it can be determined by carefully measuring flow for one pressure (or head) and making the construction indicated by dotted lines. This factor can then be used for any pressure as measured with the given orifice set-up.

Indicated factors for orifices with sharp-edged and well-rounded entrances apply wherever orifice discharges freely from a tank or pipe much larger than orifice. Where orifice is used as meter in a pipe, same factors apply with reasonable accuracy if orifice diameter is not over ½ pipe diameter and pressure taps are 1 diameter upstream and ½ pipe diameter downstream.

For orifices larger in relation to pipe, or for other positions of pressure taps, run a test to determine factor, or consult flowmeter handbooks.

PRACTICAL AIDS TO OPERATION



Protects Oil System With Two-Way Cock

ONE exception to the rule: "Never place a shutoff valve of any description on a safety-valve discharge," will be found in some fuel-oil systems. In the diagram the pumping and supply system is installed in duplicate. The heating system may be installed in duplicate, also, but as it does not change the relief-valve arrangement, a single heater is shown for simplicity.

It is common practice to pipe the header from the discharge of the relief valves back to the oil-storage tanks. Where more than one storage tank is installed, it is not uncommon to tee-off the discharge header into each tank, with a shut-off valve in each tank line so that the line may be closed to a tank out of service for repairs. Assume that on completion of repairs, it is desired to put tank No. 2 in service and open tank No. 1 for repairs. If the workmen close valve *B*, but forget to reopen valve *A*, a closed condition now exists in the relief-valve discharge system. If the pressure-regulating valve on the oil-pump discharge become defective, an excess pressure on the system would probably result, with failure of the weakest part.

By removing the tank-line shut-off valve and installing a 3-way cock of correct design, the possibility of trouble is eliminated. The lever can be in only one of two positions, either of which will give free passage to one of the two tanks. The cock used should be designed so that through passage is not closed when the lever is midway between the two positions.

Boston, Mass. C. O. DIBBLE

Guards Made From Pipe and Steel Strapping

BUILDING suitable guards for machines and motors is a problem that confronts every plant maintenance man. In most cases it is desirable that the guard prevent employees coming into contact with equipment while it is operating, and yet leave the machine visible. For motors, speed reducers and other devices that generate considerable heat, it is necessary that a guard be sufficiently open to allow free air circulation.

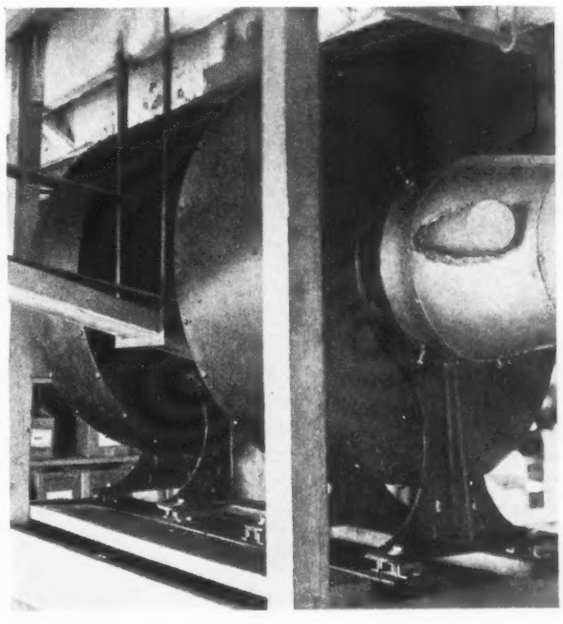
A very good form of guard that can be varied to suit different conditions is made of a combination of pipe and steel strapping. The pipe may be fitted in most any desired manner, size and shape. Lengths of steel strapping, such as are used in the packaging, are woven basket fashion about the pipe structure, and are either brazed or spot welded at points to insure that the straps will hold their position. Guards of this type have the advantage of being fabricated from materials that are generally available.

Peoria, Ill. JOHN E. HYLER

Rubber Mounting Solves Vibration Problem

IN VIEW of the trend towards heavier, higher-speed machinery, many equipment builders have recognized the necessity of incorporating provisions for minimizing effects of vibration. However, there are thousands of machines now in use for which no such provision has been made. Users seldom feel justified in going to the expense of having special mountings engineered to their needs, nor are they equipped to handle this problem in their own shops.

Such was the situation faced by the Indiana Ox Fibre Brush Co., Seymour, Ind. A double blower on the third



floor of their plant presented a serious vibration problem. This blower, weighing approximately 1,000 lb., is driven with a belt between the two fans. Power is supplied by a 15-hp. motor at 1,800 r.p.m., which drives the fan at 1,250 r.p.m. The blower is mounted on a raised platform, and the vibration not only affected the building structure immediately around it, but was also transferred to the floor above.

The problem was successfully solved by a small investment to mount the blower on a series of 3-in. long rubber-to-metal mountings of the double-shear type which permit attaching of machine base directly to the top insulator.

This type of mounting will support a maximum load

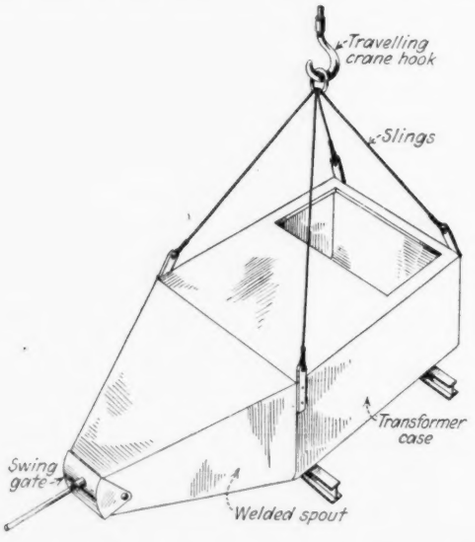
of 150 lb. Therefore, to support the 1,000-lb. load, eight were installed at various points under the frame, as in the photograph. Vibration has been dampened to the point where it no longer is causing deterioration of the building structure and permits unrestricted use of the floor space above.

Akron, O. R. W. SMITH
B. F. Goodrich Co.

Homemade Skip Solves Concreting Problem

SOME TIME AGO, we had to pour a lot of concrete in our plant. Conditions were such that it was impossible to set up a mixer near the work area. To handle the concrete from the mixer, a skip was made from an old transformer case to which a spout was welded, as in the figure. A swinging door operated by a lever closed the discharge end of the spout. The skip was equipped with slings so that it could be handled by a 5-ton traveling crane.

By the use of this skip and the crane, 200 cu.yd. of



concrete were placed, some of it in places where it would have been very difficult to pour by any other means. The sling was arranged so that the skip hung at an angle of 45 deg., a position that caused the concrete to flow out easily.

Arcadia, Calif. M. C. COCKSHOTT

Inside Versus Outside Calking of Boiler Plates

TIGHTNESS against leakage of riveted plates in steam boilers and unfired pressure vessels is accomplished by calking. Inside calking consists of calking the plate or butt strap from the pressure side only. Outside calking deals with seams on the external surfaces. Most authorities prefer inside calking of riveted seams in construction of new boilers and drums, as well as for major repairs.

Inside calking of plates or butt straps prevents seepage and accumulation of solids from the boiler water between the plates. Where the seam is exposed to the fire, the insulating qualities of solids between the plates may cause so-called fire cracks or rivet-hole fractures of the lapped plate. Many fire cracks blamed on various causes have developed from this source. Locations particularly susceptible include the girth seams of horizontal-tubular boilers, vertical seams in furnace sheets of vertical tubular boilers, and furnace-sheet seams of locomotive-type boilers.

A further possibility of detrimental effect in the outside calking method is that presence of certain boiler waters between the plates may have a tendency to induce corrosion or embrittlement.

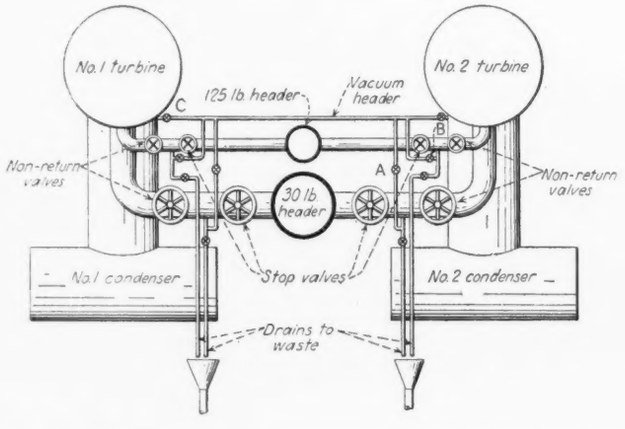
A third point, possibly still controversial in absence of definite data, applies especially to riveted seams of the butt and double-strap construction. The outside butt strap is sometime calked pressure-tight, and inside calking is eliminated. It is then possible for slight leakage to pass between the boiler shell and inside strap, through the abutting shell plate edges, and against the inner surface of the outside strap. This action of pressure would cause a distorting tendency by complicating the stresses in the outside butt strap. Relief of pressure against its inner surface is obtained only by failure of its calked edge, allowing leakage flow past the inner strap.

Some types of boilers have constructional details which make inside calking impracticable. However, where possible, most authorities on boiler construction advocate inside calking.

Columbus, O. J. R. WILLIAMS

Prevents Steam Leaks Into the Idle Turbine

AN INDUSTRIAL plant operating two 3,000-kw. double-extraction turbines encountered difficulty due to steam leaking from extraction headers into the casing of the shutdown unit. Hand-operated stop valves on the turbine-extraction lines were not absolutely tight and permitted a small amount of steam to leak past them. This



steam got into the spaces between the stop valves and the oil-operated non-return valves. From here most of it would escape through the drain lines to atmosphere, but a small quantity would get through the comparatively loosely fitted non-return valve and into the turbine casing. Condensation of this steam in the casing kept the turbine constantly moist, producing rusting and aggravating the corrosive tendencies of solids taken into the turbine by the superheated steam during its operation, and not carried through.

To overhaul the stop valves and make them tight would have required shutting off process steam to the factory for several hours, involving a prohibitive financial loss. The difficulty was corrected without shutting off

the process steam by connecting the spaces between the stop and non-return valves into the exhaust connection from the turbines, as in the figure. This allowed pulling any steam that leaked past the stop valve, into the condenser of the running unit. Furthermore, by inducing a slight flow of air through the shaft packing and casing of the idle machine, its interior was kept dry.

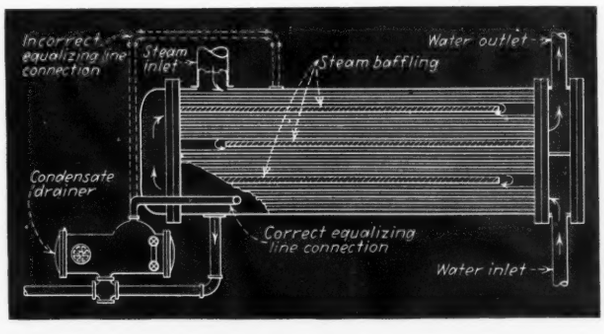
Connections were easily made. Copper tubing 0.5 in. in diameter was tied into the existing drain lines ahead of their stop valves. When unit No. 1 is in service and No. 2 shutdown, valves *A* and *B* are opened wide and the flow controlled by valve *C*. In practice it has been found that valve *C* should be throttled, for when it is wide open vacuum in the condenser is slightly impaired. The change has, however, completely rectified the trouble.

New York, N. Y. JOSEPH GISH

Improper Heater Connection Causes Low Temperature

FREQUENTLY, improper performance of equipment results from misinterpretation or ignorance of manufacturer's installation and operating instructions. Where power-plant supervision is lax, and installation errors or operation remain uncorrected, the direct financial loss occasioned by excessive maintenance and reduced efficiency is often large.

An instance of improper installation was recently uncovered in the feedwater heating system of a large industrial power plant. During a gradual increase in station load, caused by an enlargement of manufacturing facilities, feedwater temperature at the closed-type extracted-steam feedwater-heater outlet dropped 40 deg. below the guaranteed temperature. As some difficulty had been experienced with scale in the heater before the increase in load, it was assumed that poor heat transfer caused the temperature drop. The heater was opened and the slight scale in the tubes removed, but there was



no appreciable gain in feedwater temperature when the heater was replaced in service.

After every obvious factor which might cause the decrease in temperature was checked unsuccessfully, the trouble was finally found in the drainage system. An operator noticed an increase in feedwater temperature when the bypass around the external-float controlled drainage device was open. This discovery, while pointing to improper drainage, with a resulting flooding of the lower tubes in the heater, served only to increase the mystery surrounding the behavior of the equipment, because the water level indicated in the float-chamber drainer gage glass was below the heater shell bottom.

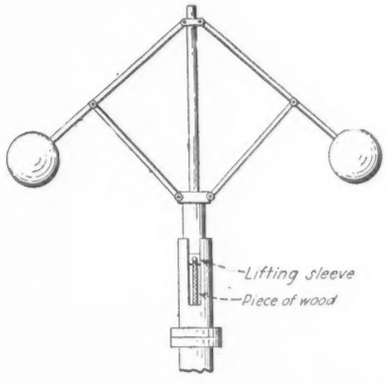
At this point someone happened to remember the manufacturer's installation drawing. It was found that the balancing line between the drainer float chamber and the heater steam space was incorrectly connected into the first steam pass of the heater. As a considerable pressure drop existed through the steam passes, water condensation would rise in the heater shell to a height corresponding to this drop in pressure, flooding the lower tubes and reducing effective heat-transfer surface. With the balancing line reconnected into the last steam pass, according to the manufacturer's recommendations, no further flooding was experienced and feedwater temperature consistently bettered the guarantee.

Roanoke, Va. H. S. COLEMAN

Blocked Governor to Keep Unit in Service

IN ONE plant with which I was connected power was supplied by three Corliss engines belted to alternators. To carry the load it was necessary to operate the three units in parallel for several hours each day. The governor belt on one unit began tearing apart directly back of the lacing. When discovered it was holding by but one-third the width of the belt. It was necessary to act quickly if we were to avoid an interruption in service.

An oiler was first instructed to take a slight strain on



the reach-rod lever, to take off the belt most of the weight of the loaded governor. Then a measurement was taken to determine the height at which the governor was riding. A small piece of wood was cut the required length and inserted between the stop and the lifting sleeve, as in the figure. The engine then of course had a fixed cut-off, and variations in load were taken care of by the other two units. After operating for several hours under these conditions, the load dropped off sufficiently to enable us to remove this unit from the line and replace the governor belt.

St. Paul, Minn. E. R. WEBBER

Rebuilt Windbox Wall Improved Boiler Draft

ON ONE of the boilers in our plant, fired with a stoker and forced-draft fan, we noticed cracks in the brick walls of the windbox. We took down the walls and drilled holes into the ashpit base. Into the holes we put $\frac{3}{4}$-in. reinforcing rods, made wooden forms and poured concrete into them to make the new walls. These walls are the length of the wind box and are 8 in. thick. This change improved draft considerably, and no evidence of cracks in the concrete has developed.

Chicago, Ill. ABE ROCKLIN

CURRENT COMMENT

Basement Explosions

I HAVE a theory which may explain the rather numerous gas explosions in the basements of buildings throughout the central west during the extremely frigid weather just passed.

Natural-gas pipelines welded in place or welded and lowered in trenches without any provisions to put the line under an initial compression, were contracted by frost or by coal gas. The gas cooled at points where the cover was slight. The result was the pipes snapped in places causing leakage. This leakage normally would travel upward and seep through the soil. However, the entire soil being an impervious frozen sheet or blanket, caused the gas to seek other adjacent trenches in which sewers were located, and entered these sewers. This gas would then travel to basements with defective traps and collect in quantity for a violent explosion.

I have thought that where gas lines are exposed to the atmosphere at bridge or stream crossings (i.e. where carried over a stream by a bridge), they should carry an insulation sufficient to prevent extreme cooling of the gas. However, the importance of laying all-welded gas lines under initial compression is quite evident to me.

I should like other readers' opinions on these points, including the consideration of gas temperatures.

Columbus, Ohio V. A. EBERLY

Cylinder-Oil Consumption Varies With Compressor Speed

THERE appeared in July *Power* an article "Compressed-Air Explosions," in which G. B. Comfort states that oil consumption in a vertical single-acting air-compressor is affected by the pressure or vacuum in the cylinder. The theory on which this article is based is parallel to the common belief that in an engine or compressor, passage of oil into the combustion or compression chamber is influenced by pressure of vacuum in the cylinder. This theory is in error, for the actual quantity of oil passing the piston rings is found to be a function of speed alone. Pumping pressure set up by the rings is of far too high an order to be influenced by any relatively slight difference of pressure or vacuum in the cylinder.

What actually happens is:

1. On the piston down-stroke oil scraped off the cylinder walls sets up a heavy hydraulic pressure, and this plus friction of the rings on the cylinder walls forces the rings against the top face of the grooves. Clearance between the lower sides of the rings and their grooves, also the space behind the rings, is filled with oil scraped from the cylinder walls.

2. When the piston rises, the rings change over and bear against the lower face of the groove, passing oil behind the rings to their upper face.

3. At the top of the stroke, when the rings change sides again, some of this oil will be squeezed out. Each ring functions as a valveless oil pump and delivers oil into the compressing chamber on each stroke.

4. On badly worn cylinders, pistons and rings, the oil consumption is greatly increased because more oil can pass by the piston skirt and get by the piston rings due to more space between the rings and their grooves.

If Mr. Comfort's contention that "pressure in the cylinder tends to drive back any oil," were true, it would be impossible to lubricate a badly worn compressor. We all know, however, from experience that wear greatly increases oil consumption. The fact is that oil consumption, under a given set of conditions, varies almost directly with the speed of rotation.

I have made many laboratory tests on oil consumption of compressors and the curves from these tests show the findings. They prove that neither pressure of vacuum in the compressing chamber has any effect

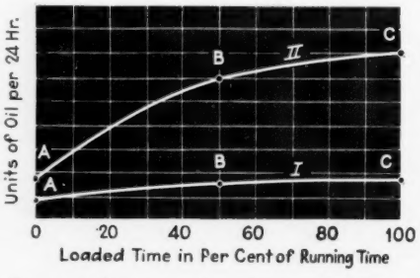


Fig. 1.—Oil consumption of a compressor at constant speed

Curve I is for a compressor in good condition. Curve II obtained from badly worn compressor. Points *A* represent oil consumption when compressor is unloaded, *B* when compressor is loaded 50% of the time and *C* when the compressor is loaded all the time

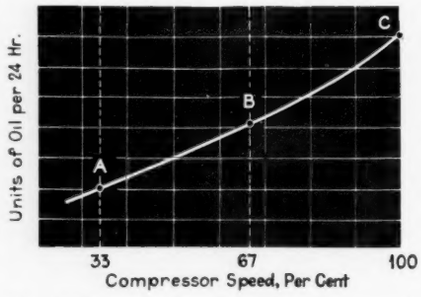


Fig. 2—Compressor oil consumption operating at different speed

Point *A*, oil consumption at 33% speed, point *B* 67% speed and *C* 100% speed

on oil consumption, whereas the speed of rotation does have a direct effect on the amount of oil used.

Curve I, Fig. 1, was obtained for a single-acting vertical compressor equipped with a regulator which closes the intake during unloaded periods. The compressor ran at a constant speed. *A* represents oil consumption when the compressor was completely unloaded, *B* oil consumption with compressor loaded half the time and unloaded the other half, while *C* is with the compressor fully loaded all the time. The compressor was run several days under each condition. This curve shows that when the compressor is unloaded by a regulator which closes the intake, oil consumption is not increased. It also shows that a partial vacuum above the piston does not have any tendency to suck oil out of the crankcase. In fact, oil consumption is less with a partial vacuum than it is with 100-lb. pressure above the piston. Increased oil consumption at *B* and *C* is due to the higher temperatures when operating under load. Otherwise, the oil consumption at *B* and *C* would have remained the same as at *A*.

Curve II, Fig. 1, gives actual oil consumption of a compressor with badly worn pistons, rings and cylinder walls. The same type and size of compressor and unloading system was used as represented by Curve I. It will be noted that at all three points *A*, *B* and *C*, the oil consumption is much greater than in Curve I. This is due to the worn condition of cylinders, pistons and rings, as previously explained. Furthermore, even with greatly increased clearances (wear) the amount of oil used when unloaded was less than ¼ of the amount used at full load. Fig. 2 shows the oil consumption of a compressor running loaded at a constant pressure but at three different speeds, and indicates that the amount of oil consumed varied almost directly as the speed of rotation.

Harry Ricardo, the eminent English research engineer, in his book: "The High-Speed Internal-Combustion Engine" tells of oil-consumption tests he has conducted which substantiate the foregoing, and he says: "The author has carried out a number of tests in order to ascertain the influence of both pressure and speed on the passage of oil into the combustion chamber, and has tried the effect of motoring an engine and collecting the oil passing the piston under the following conditions:

1. When pressure on either side of the piston is atmospheric.

2. With a continuous vacuum of 20 in. of mercury in the cylinder.

3. With a continuous air pressure of 45 lb. per sq.in. above the piston.

"In all three cases the quantity of oil passed per hour was, within the limits of observation, the same. In all cases also the quantity of oil passed by the piston varied almost directly as the speed of rotation."

Corning, N. Y. J. W. JONES

Not Guilty

I NOTE in the March "Current Comment" that Mr. Bell mentions "Let us not forget, even with our short memory, that Federal Inspectors licensed the men who have just been found guilty for the exploits on the *Morro Castle*, etc." May I ask, guilty of what? I note in Mr. Bell's article he infers he progressed through "the priceless training of ocean tramp steamers." Over 1,000 members of the Marine Square Club, 311 West 23rd St., New York, N. Y., an organization composed chiefly of licensed officers, are in disagreement with this verdict according to an

editorial in the March, 1936, Bulletin. The Licensed Officers Assn., composed solely of masters, mates and engineers, has also gone on record as being against the verdict.

We fail to see where a man should be convicted for doing the best he could under the circumstances. Hindsight is much better than foresight. In case of a fire at sea one has to think quickly, one hour passes like five minutes. The writer has been in two serious marine fires as engineer officer, in one of them the vessel was gutted, so has a regard for a person caught in similar circumstances. May I ask that judgment by laymen be withheld on the unfortunate victims of mob hysteria, for those in a position to judge, men who have spent their lives at sea and who have been in fires, do not believe them guilty, even if they did make errors of judgment.

Plainfield, N. J. WM. P. LAMBERT

More on Obtaining Proper Sulphate-Carbonate Ratio

AFTER reading R. G. Rea's article in October *Power* on sulphate-carbonate ratio in boiler water, I believe *Power* readers would be interested in my experience with the same problem.

In 1928 a large paper company, with which I was connected as assistant chief engineer, built a new power plant. Boilers delivered steam at 400 lb. pressure, 750 deg. F. total temperature, and were operated at 300% rating. After we started operation we found that the sulphate-carbonate ratio was about 1 to 4, or just the reverse of what it should be. We first tried to correct the ratio by feeding sodium sulphate, but this caused the total concentrations to increase so rapidly that it was not practical to take care of it, even with a continuous blowdown.

After quite a bit of research through chemical textbooks and experiments on boiler-water samples, we finally discovered that alkalinity of boiler water could be changed over to sodium sulphate by the addition of a relatively small amount of sulphuric acid. The acid was fed into the water softener by a dropper, manually controlled by the operator.

At the start of this treatment, the boiler feedwater at the feedwater heater was tested hourly for acidity. After a few weeks of experiment, we found that the treatment was very easy to control and was giving us the desired result—namely, conversion of high alkalinities in boiler water over to sodium sulphate and a consequent bringing into line of sulphate-carbonate ratio to conform to A.S.M.E. recommendations.

Richmond, Ind. H. L. HAWORTH

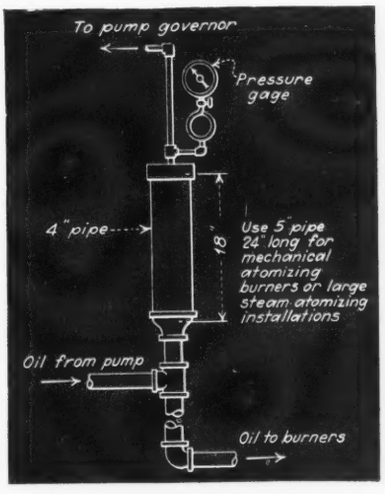
Cushion Chamber Prevents Oil-Fire Pulsations

THE article, "Cushion Chamber Prevents Oil-Fire Pulsations," by J. R. Williams, in October *Power*, brings out an important factor in maintaining a non-pulsating flow of oil to the burner. When oil is delivered to the burners by motor-driven rotary pumps, an air chamber on the discharge line is not generally considered necessary. On reciprocating pumps, the air chamber shown by Mr. Williams might be satisfactory, but it usually will be better practice to install one of larger capacity. This is particularly true for mechanical-atomizing burners.

The diagram shows an air chamber used by one maker of steam-atomizing burners. It is practically identical with that suggested by Mr. Williams, except that it has about four times the capacity. Sometimes, 5-in. pips are used instead of the 4-in. size shown. The diagram shows a convenient way of mounting the pressure gage and making the pump-governor control line connection. If the pointer of a gage, in this location, remains steady, no serious pulsation exists in the oil line and conditions are satisfactory for the pump control.

An air chamber like that shown, preferably 5 in. in diameter and 24 in. long, has been found satisfactory with mechanical-atomizing burners, but one maker of these burners requires an air chamber of even greater capacity.

Careful consideration should be given to the possibility of gas pockets forming in the discharge line. With steam-atomizing burners, when the discharge line is under comparatively low pressure, if vertical loops exist in the line, gas may accumulate in these and later go through to the burner and cause puffing. For mechanical-atomizing burners, using pressure around 200 lb. and oil temperature of 200 deg. F., instantaneous low pressure due to large pulsations may aid in formation of gas bubbles that will cause trouble at the burner. It is therefore necessary that a steady flow of oil be maintained to the burner for satisfactory operation.


To pump governor
Pressure gage
4" pipe
18"
Use 5" pipe 24" long for mechanical atomizing burners or large steam atomizing installations
Oil from pump
Oil to burners

Bloomfield, N. J. JAMES O. G. GIBBONS

Simple Brine-Tank Thermometer

IN *Power* for October, page 564, Fred W. Schneider describes how he simplified the reading of a brine-tank thermometer by putting an automobile starting switch and electric light inside the tank under a glass cover. He could have improved the job, with less trouble and expense, by using a Taylor industrial long-stem thermometer set at any angle he wanted it. The scale would be outside the tank, easy to read, and there would be no wiring or light inside to cause eventual trouble.

Rochester, N. Y. W. J. GESSNER

Paint Maintenance Is Mostly Proper Cleaning

PAINT maintenance problems were discussed at a power-plant round-table of the Metropolitan Section, A.S.M.E., Oct. 28. Mr. O'Neill of Brooklyn Edison pointed out that labor in cleaning and painting is 90% of cost, and that cleaning is more important than any other factor.

Each man should have the responsibility for certain work, the work he does being recorded on a job ticket. Each cleaner is made responsible for one girder, or one column, etc., and considerable competition can be created, all of it resulting in better work. A man who makes good on one job is favored for advancement, of course—thus a second-class painter is given a chance occasionally at a first-class painting job, etc. In any case, the foreman functions only as an inspector.

Safety in painting is 50% indoctrination of safe practices and 50% proper equipment. Brooklyn Edison has found that its best tool is a set of tubular steel scaffolding to replace the former makeshift wooden scaffolding. Foremen check to make sure that the scaffolding is finished before any man starts painting. Monthly inspections are made of all painting and equipment, all data kept in a complete record system.

The record system is particularly important in testing paint. To avoid haphazard painting, each paint job is stencilled with the date of painting, the name of the painter, whether brushed or sprayed, method of cleaning before painting, paint used, weather. Stencilling makes the whole plant a paint laboratory and also permits any good paint to be duplicated through check-up with the manufacturer.

The paint inside a window may have to be entirely different than that outside, and the paint in the turbine room should have different characteristics than that in the boiler room. It is now common practice to paint up several panels with sample combinations, *then to test them where they are to be used.* The latter is most important. If a paint is to be used outside, test panels should be circular so they get wind and sun from all sides, and if the paint is to come in contact with the ground, the panels should likewise. Brooklyn Edison has a test rack right in the screen well house.

Brooklyn Edison has found it best to sandblast where possible in preparing a surface, Mr. O'Neill saying flatly that, "No chemist can obtain in any paint the base which is obtained by sandblasting." Outside the plant, a shanty is used as a sandblasting room; inside, a dead boiler makes an admirable sandblasting room. Where required, paint is chipped off either by hand or pneumatically.

Metal spray as a substitute for painting has failed in many cases, but specifically on radiators, zinc spraying stood up better than any paint used. Aluminum paint was found good for surface coats, but not satisfactory as a base or primer coat. Red lead as a primer appeared best where its cost could be justified by the life of the equipment, but some difficulty has been experienced in getting it to dry in reasonable time. Inside, where both primer and second coat must be put on in quick rotation before the scaffolding is moved, a faster-drying primer may be better.

READERS' PROBLEMS

QUESTIONS for Our Readers

Diesel Maintenance

Question 1

WE *are planning a 3-engine diesel plant, using two 500-hp. engines and a 750-hp., all of the same bore and stroke. It is to supply power for a group of mines in an isolated place. What should we figure on in the way of spare parts for the diesels, and what tools are essential for a maintenance shop capable of handling efficiently any normal repair job?*—T.T.R.

Flexible Couplings for Long Lineshafts

Question 2

WOULD *some POWER readers give me their experience with flexible couplings and self-aligning anti-friction bearing hangers on lineshafts? We have been experiencing a lot of trouble in keeping lineshafts in alignment in our plant, which is of mill-type construction. The shafts range in length up to 100 ft. and run in babbitted bearings, the hangers being supported from the beams of the floor above. Changes of loading on this floor make it impossible to keep the shafting in proper alignment.*—M.W.D.

Suitable answers from readers will be paid for if space is available for publication.

TESTING AIR-CONDITIONING

ANSWERS to October Question 1

The Question

THIS *year we installed an air-conditioning system that was guaranteed to maintain 80 deg. dry bulb and 50% relative humidity when the outside temperature is 95 deg. and relative humidity is 40%. Since the system was placed in operation, we have had only one period when the outside temperature was this high, and this was not long enough to test the capacity of the system. There have, however, been a number of hot days with high humidity when it has seemed that the system was not producing sufficient cooling. Is there any way in which I can determine whether the system has guaranteed capacity on days when the outside temperature is lower than that specified in the guarantee.*—K.V.M.

Test with Same Temperature Difference

K.V.M. gives very little data on which to base a reply. There are many conditions that should be known in order to work out a test condition for his installation.

However, all air-conditioning is based on the transfer of heat through building materials, or heat flow.

The rate of heat flow depends (for one factor) on the temperature difference between the inside and outside air. In the absence of any other data I believe that K.V.M. can get a very good idea of the relative capacity of his air-conditioning system at any time with a temperature difference of 15 deg. F. between the outside and inside temperatures. (95°—80° = 15°).

For instance: If the outside temperature is 70 deg., set the automatic control at 55 inside. Pick a bright sunny day to get as much sun effect as possible to run the test the desired number of hours.

If the system maintains the temperature at 55 deg. with a relative humidity 50%-60%, I believe the system can be relied on to perform as guaranteed.

Waterbury, Conn. FREDERIC W. CARTER

Complete Field Test Not Possible

The problems encountered in testing an air-conditioning system in the field are such that no completely satisfactory test can be made, even under stated conditions. The temperature and humidity in a specified space can easily be determined, but it is difficult to determine if they are produced at the specified amount of energy and condensing water.

The required conditions may be attained at the expense of more air circulation or less than the minimum amount of fresh air. Either of these quantities would be difficult to check. Perhaps the condensing water may be greater than that called for under the guarantee. This can be checked more accurately than the previous medium but requires costly apparatus.

Even though all measurements could be made accurately, unless a set of test curves of the conditioning unit were available, the test conditions could not be translated into guarantee conditions because the capacity as a function of temperature and humidity and air quantity is not a straight-line equation.

Conceivably, a number of tests could be made to determine the approximate form of the performance curve, and if they were close enough to the guarantee conditions the curve might safely be extended to that point. But this would involve so much work and apparatus to get even fair results that unless the installation involves a great deal of money it would be just as well merely to say that the conditioned space was comfortable and that power and water bills did not exceed expectations.

Waynesboro, Pa. HUGO RICHENBACH

May Be Meeting Guarantee

PERFORMANCE of an air-conditioning system is far from being a matter of merely cooling the air. Whether or not an air-conditioned space is comfortable or not depends to a very great extent on the relative humidity. The investigations of the American Society of Heating & Ventilating Engineers and of the Harvard School of Public Health, which have been given wide publicity, resulted in the introduction of the term "effective temperature" air at 95 deg. and 40% relative humidity has an effective temperature of about 83 deg. and a heat content of 38.5 B.t.u. per lb. of air. At 80 deg. and 50% the values are 74 deg. and 31.3 B.t.u. Effective temperature is reduced 9 deg., and each pound of air has had removed from it 7.2 B.t.u.

Now let us suppose that on the hot days with high humidity the outside temperature was 90 deg. and the relative humidity 70%. For this condition the effective temperature is 84.5 deg. and heat content is 45.1 B.t.u. per lb. of air. If the same cooling effect is to be obtained, the effective temperature will be reduced the same amount, and inside effective temperature should be 84.5 — 9 = 75.5 deg. The effective temperature in the second case is 1.5 deg. higher than in the first, even though the outside temperature is lower.

If the cooling system is to remove the same amount of heat in each case the heat content of the conditioned air in the second case will be 45.1 — 7.2 = 37.9 B.t.u. per lb. of air. Air having an effective temperature of 75.5 deg. and heat content of 37.9 will have a wet-bulb temperature of about 74.5, as against a wet-bulb temperature for the guarantee conditions of 66.5 deg. The corresponding relative humidity is about 90%.

It is entirely possible that the equipment is meeting its guarantee even though it is not producing comfortable conditions. A higher humidity of outside air should have been provided for in the original guarantee.

Corvallis, Ore. W. H. MARTIN

HOW TO CLEAN MOTOR WINDINGS

ANSWERS to October Question Number 2

The Question

I WOULD *like to know what methods and materials POWER readers have found most suitable for cleaning motors? Coils in several of our motors become covered with oil, while a dust and dirt from processes collects on others and adheres to the insulation, particularly in the presence of moisture. In the latter case, water will clean the windings, but I am wondering if it is advisable to use water for this purpose under any circumstances?—R.V.*

Machine May Require New Insulation

DO NOT use water, under any circumstances, to clean electrical equipment. Fluids can be purchased compounded especially for cleaning motors and other electrical equipment. If these cannot be obtained readily, carbon-tetrachloride will serve equally well. High-test gasoline may be used, but care must be taken not to create a fire or explosion hazard.

The cleaning fluid may be applied with

a brush until all dirt and oil are removed. Where clean, dry, compressed air is available at about 50 to 75 lb., first use it to blow out as much as possible of the dirt before applying the cleaning fluid. After the winding has been cleaned, the insulation may be found in poor condition. If so, reinsulate or rewind the machine. In most cases, one or two coats of good air-drying insulating varnish will be all that are needed.

Vere Beach, Fla. HOMER D. WHITE

Recommends Carbon-Tetrachloride

A CLEANING solution having a carbon-tetrachloride base is recommended for cleaning motor windings. It has the advantage over gasoline of being non-inflammable and will also evaporate quickly. In addition, it will cut any oil or grease which may be adhering to the motor insulation.

As regards the use of water for cleaning, standard induction motors as now manufactured will stand moderate amounts of moisture. It should be realized, however, that moisture does not do motor windings any good. Best practice dictates a thorough drying out of motors that have become wet by circulating a current through the windings to produce a temperature of about 90 deg. C.

Consideration should also be given to the age of the motors. Whereas induction motors built today will stand moderate amounts of moisture, or even weak acids and alkalies, insulation of many motors built some years ago was not nearly as good. In fact, if it were known that motors were to be subjected to moisture, the motor manufacturer would take special precautions in applying the insulation. Consequently, it is advisable to be extra careful in cleaning the insulation of old motors.

Schenectady, N. Y. R. F. EMERSON
General Electric Co.

Uses a Petroleum Solvent for Doing the Cleaning

WE USE a petroleum solvent, "Varsol," for cleaning oil from insulation. Small motors can be washed or soaked in it, then dried by putting in the sun, or baking, or blowing out with compressed air. The fire hazard is to be reckoned with, however. Large motors can be washed with a brush or waste and dried by wiping or with compressed air.

Modern motors may be washed with water if this solvent will not clean them, but it will not do to wet laminations and the parts of coils that are in slots. Capillary attraction will suck the water in, and only baking will remove it. When the winding has been cleaned and dried, finish the job by giving it a coat of good air-drying varnish with either a spray gun or brush.

Leesville, S. C. F. E. BRODIE

Not Advisable to Use Water for Cleaning Windings

CARBON-TETRACHLORIDE is about the most effective fluid to clean oily motor windings. It will readily loosen sticky and oily deposits unless the windings have become encrusted. In such cases, the encrusted dirt can usually be removed with dull-edged scrapers or wire brushes, followed with a final cleaning with carbon-tetrachloride. A satisfactory means of applying the fluid is to use some form of a spray gun, such as a fire extinguisher, under about 80-lb. pressure.

While gasoline is an effective solvent and may be used for washing oily windings, carbon-tetrachloride has the advantage of being non-inflammable and at the same time evaporates quickly. However, when using it, be careful not to inhale the fumes, since they are somewhat toxic. Unless good ventilation can be provided, it is advisable to use a gas mask.

While it is not generally advisable to use water for cleaning windings, it is sometimes used when foreign deposits are readily soluble in water. When water is used, every trace of moisture must be dried out of the windings before returning the motors to service. This can hardly be done except in a suitable oven where a constant temperature of 190 to 200 deg. F. is maintained. After a thorough cleaning and drying, it is always advisable to make an insulation resistance test, and if an unsatisfactory reading is obtained, to give the windings either a dip or brush coat of a good insulating varnish which will probably restore the insulation resistance to a good value.

St. Mary's, O. J. L. YOUNG

Suggest Removing Causes of the Trouble

BEFORE considering methods of cleaning motor coils that have been covered with oil, dust and dirt, it is preferable to eliminate the causes. All oil connections should be thoroughly inspected and tightened up. There is no excuse for oil dripping from motors or being spattered over the coils. If the oil comes from outside sources, then take steps to stop it. It is possible that the motors could be protected to advantage with some form of insulating-board enclosure.

To prevent dust and dirt collecting in the motor windings, there are totally enclosed types on the market which successfully run in a dirty atmosphere, chemical fumes, etc. As previously mentioned, however, steps should be taken in manufacturing processes to prevent dust and dirt arising at the source.

After looking into the causes of the oil vapors and dirty atmosphere, and taking steps to stop them, then cleaning methods may be considered. Of these, dust and dirt may be removed by vacuum cleaners; and there are cleaning compounds made for removing oil, dust and dirt. Frequently, water will cause short circuits in the motor windings, so before using it get in touch with the motor manufacturer and find out if the insulation would be injured.

New Dorp, N. Y. CHAS. H. HUGHES

Denatured Alcohol Used to Loosen the Dirt

WATER must never be used for cleaning motor windings or other electrical equipment. If compressed air is available, clean out loose dirt by air pressure. If compressed air is not available, a portable blower should be obtained. It will prove to be a good investment and a valuable tool for many purposes.

After the loose dirt has been blown out, use denatured alcohol to loosen the remaining oil and dirt. This can be applied by using an ordinary hand fire extinguisher. Apply the air blast again to remove the dirt which has been loosened, and the results will be entirely satisfactory. Reasonable care should be practiced when using alcohol in a confined space or near a flame. Under ordinary operating conditions, it is a convenient, quick and inexpensive fluid, evaporates readily and the machine is ready for service immediately after cleaning.

Kearny, N. J. GEORGE MCNALLY

Recommend Spray Gun for Doing the Work

FOR cleaning grease and dirt from motor windings, I have found where compressed air is available that a commercial or home-made spray gun, giving a strong blast of air and cleaning fluid, is most efficient. Cleaning fluid can be applied with a medium-bristle brush, if compressed air is not available.

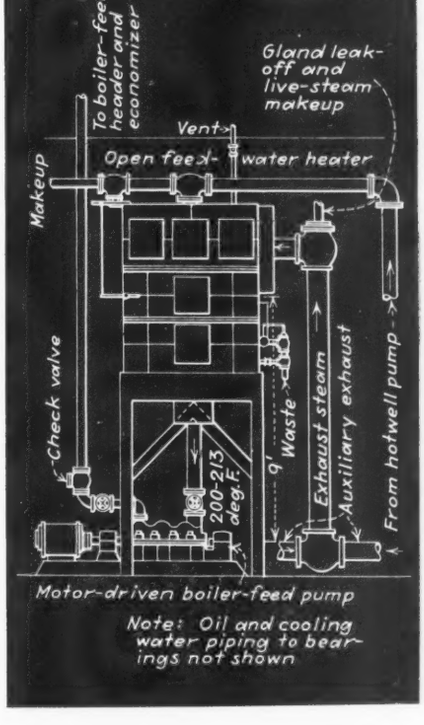
If the motors are small and can be cleaned where there is no danger of fire, gasoline is probably the lowest-cost cleaning fluid to use, but on large motors or where there is the danger of fire, some non-inflammable cleaning liquid should be used, such as carbon-tetrachloride.

After windings are cleaned and allowed

WHAT'S WRONG WITH THIS PICTURE?—X

Feedwater Heating System

THERE are at least 10 mistakes in this drawing. Make a list of those you recognize, then check against the list on page 688.



to dry, a good grade of insulating varnish should be applied to them, either with a brush or preferably by a paint spray gun. A paint spray gun is not suitable for cleaning as it will not give a sufficiently strong blast of liquid vapor to produce an effective solvent and washing action on the grease in the windings.

Do not use water to wash motor windings unless the winding is already water-soaked from a flood, then a hose may be used to wash mud from the windings before the machine is placed in an oven for drying.

Richmond, Ind. H. L. HAWORTH

Use Motors With Specially Insulated Windings

THE greatest detriments to motor-winding insulation are the two factors which R. V. mentions—oil and moisture. A thorough overhaul of the motor bearings to eliminate oil seepage is first in order, then care when filling them will go a long way toward keeping the oil where it belongs. For removing oil from motor windings, periodical cleaning with benzine, gasoline, or carbon-tetrachloride is recommended. After allowing them to dry thoroughly, apply a coat of air-drying varnish. Caution: apply varnish to windings only free from moisture, as the varnish may seal in moisture and do more harm than good.

Motors which operate in moist places should be of a special class for this type of service. The increased investment will show a profit in decreased maintenance and operating costs. Home-made shields, heating elements and electric bulbs can be made and used to keep moisture from motor windings, particularly when the motor is standing idle.

There are many ways of drying out windings, the best being to circulate current at reduced voltage through them. Care must be taken, however, that inaccessible parts of the windings do not reach too high a temperature. Accessible parts of the winding should not be allowed to exceed 175 deg. F. temperature. The time required for drying will vary with the size of the machine and the amount of moisture present; continue drying as long as the insulation resistance increases. Heating in an oven may also be used, the temperature being kept as before. The oven must be ventilated to allow the moisture to escape.

Baton Rouge, La. EDWARD P. MADIGAN

WHAT'S WRONG WITH THIS PICTURE?—X

FEEDWATER HEATING SYSTEM—SEE PAGE 687

ERRORS are restricted to steam and water piping and instruments for proper and safe operation. Electrical errors and oil piping are not shown.

1. *Insufficient Suction Head on Boiler-Feed Pump.* With the indicated feedwater temperature, up to 213 deg. F., a static suction head of at least 12 ft. is required to prevent steam binding.

2. *Check Valve in Wrong Place on Boiler-Feed Pump.* The check valve should be between pump and discharge shut-off valve. Otherwise, it is impossible to repair the check valve without shutting the plant down.

3. *No Pressure Gage on Boiler-Feed Pump Discharge.* A pressure gage should be provided to check on proper operation of the feed pump.

4. *No Thermometer on Boiler-Feed Pump Suction.* Proper check on operation of the feedwater heater is impossible without knowing the temperature.

5. *No Gage Glass on Feedwater Heater.* Operation of the feedwater heater and float valves must be checked by knowledge of water level as indicated by gage glasses.

6. *No Casing Vents on Boiler-Feed Pump.* Valved vents should be installed on each stage of the pump casing. If steam- or air-bound, use of these vents may hasten recovery. They are also useful when draining the pump.

7. *No Back-Pressure Valve on Feedwater Heater.* Open feedwater heaters are usually constructed for low pressure. In the event of accidental closing of the vent valve, over-pressure might rupture the heater if it is not protected by a back-pressure valve. This valve should be adjusted to open at not over the manufacturer's specified pressure for the heater.

8. *No Pressure Gage on Feedwater Heater.* A pressure gage should be provided to check on operation of the heater and back-pressure valve.

9. *No Adjustment on Feedwater Heater Float Rod.* A turnbuckle or clevis is required in the float-valve rod to regulate opening of the valve.

10. *No Trap in Exhaust Line.* A trap should be provided in the exhaust line to remove condensate.

Flushing, N. Y. HARRY M. SPRING.

EXHAUST LINES

By E. J. Tangerman

A convenient white smoke for testing purposes, tracing pipe lines, etc., can be produced by mixing ammonia and hydrochloric acid. If only a small amount is required, bottles of ammonia and HCL can be placed side by side and the stoppers removed. Their vapors will mix to produce the smoke. If greater quantities are required, one can be poured into the other in an open pan or shallow dish. White smoke can also be produced by mixing metallic zinc powder and ammonium chloride crystals, then adding a little water. This, however, is much more dangerous, because if any moisture gets in during mixing, the materials will combine with almost explosive force.

Water consumption in New York City is at the rate of 142 *gallons per person per day. In London it is only* 43 *gallons.*

Southern engineers will be glad to learn that 90% of the world's clothing is made of cotton. If women could only be talked into cotton stockings, another tremendous market would be created, because now silk stockings are the main support of the Japanese silk industry—more silk being used for stockings than for clothes. It takes a pound of raw silk, costing $1.60, to make a dozen pairs. This year, American women will buy 420,000,000 pairs—nearly 15% more than they bought in 1929.

A hole dug straight down in the United States would not come out in China, but in the Indian Ocean.

After light bulbs have been in service for a long time, the base sometimes corrodes into the socket. As a result the bulb is twisted out of its base when an effort is made to remove it. The same sort of thing happens with both screw and cartridge fuse plugs. Corrosive gases, salt air and other foreign bodies cause the trouble. To avoid it, put on the threaded section a water solution of colloidal graphite. This will provide a lubricating film, electrically conductive, which is also anti-corrosive. Be sure, however, the graphite has dried before the bulb or plug is screwed into its socket.

Norman King's penthouse atop the Singer Building in New York has all the conveniences—including compressed air at 100 lb. 25 years or so ago, he built an elaborate model steam engine-generator set, complete even to marble base, brass railings, and so on. Every so often he walks into his penthouse storeroom and sees the model puffing away with frost riming the exhaust line. The kids get in, turn on the air, then go away and forget it. Sometimes it runs for days.

In the War for Independence 4,044 *Americans were killed. In the last* 36 *years,* 32,900 *people have been killed celebrating the Fourth of July.*

George Koehne, chief at a Tulsa cold storage plant, had a 250-hp. gas engine that had him buffaloed for a while. No matter what he did, it would deliver only 225 hp. So he took a course in gas engines, then looked over the engine again and found the trouble. He rebuilt the air and gas valves and the mixing valves and shifted to cored piston rings, and has had no trouble since. Cored rings on his little gas engine cut oil consumption from 3 gal. to 2 qt. a day.

THE ENGINEER'S BOOKSHELF

Electrical Handbook

ELECTRICAL ENGINEERS' HANDBOOK (THIRD EDITION)—*By Harold Pender, editor-in-chief; William A. Del Mar and Knox McIlwain, associate editors-in-chief. Published by John Wiley & Sons, Inc., New York, N. Y., and Chapman & Hall, Ltd., London, England. 1,300 pages, 6½ x 8½ in., 709 illustrations, tables. Semi-flexible binding. Price $6.*

Appearing in a totally different form from previous editions, this new handbook deals with electric power problems only. The electric communication and electronic sections of earlier editions now form a separate volume. This has been done to permit a more comprehensive treatment of the subjects than possible in a single volume. The encyclopedic arrangement used in earlier editions has been abandoned for a more practical sequence of topics. In addition, the size of the book pages have been increased from 4x7 in. to 5½x8⅜ in., which allows the use of a larger and clearer type and more readible illustrations.

The electric power volume has been divided into 19 sections, headings of which include: mathematics, units and symbols; properties of materials; electric circuits and lines; resistors, reactors, magnets; measurement and measuring apparatus; principles of electrochemistry; batteries; direct-current machines; alternating-current machines; transformers; converters and rectifiers; switching, control and protection; power stations and substations; power transmission and distribution; lighting and heating; industrial applications of motors; transportation; electro-chemical and electrothermal industries; and electricity on the farm.

Thirty-seven distinguished members of the electrical engineering profession collaborated with the editors in preparation. It therefore represents a cross-section of the best thinking in electrical power engineering.

Wrought Iron

WROUGHT IRON (1936)—*By James Aston, consulting metallurgist, and Edward B. Story, chief metallurgist, A. M. Byers Co., Published by A. M. Byers Company, Pittsburgh, Pa. 59 pages, 6¼x9¼ in. Cloth covers. Nominal price $1; copies available free to inquirers on company letterhead, schools, etc.*

Wrought iron, though oldest of the ferrous metals, is probably the one about which least is known. As the new alloys become available, newspapers and magazines give their characteristics and applications, so technical men readily become familiar with them. But wrought iron is simply mentioned by name—everybody is supposed to know all about it; actually almost nobody knows anything about it.

This book is planned to meet that need, by presenting data on the manufacture, characteristics and applications of wrought iron, simply, straightforwardly, and commendably free from advertising. It is really a handbook on the subject. Its eight chapters are devoted to: Early Methods of Manufacture, Early Scientific Research, Present-Day Methods of Manufacture, Development of Other Ductile Ferrous Metals, Quality Standards, Characteristics, Principal Applications, Material Selection. A glossary of specialized terms is included.

Mechanical Catalog

MECHANICAL CATALOG (1936-37)—*Published by the American Society of Mechanical Engineers, 29 West 39th St., New York, N. Y. 382 pages, 8½x11¼ in.*

This year's edition, the 26th annual, has a new index feature, "Classified Catalog Index", which brings together competing or allied products under a specific class, so that no matter where in the book a manufacturer's catalog appears, its content is available to the user. Addresses are also now included in the "Classified Index to Manufacturers".

Arc Welding

PROCEDURE HANDBOOK OF ARC WELDING DESIGN & PRACTICE (4TH EDITION). *Edited by A. F. Davis, vice-president, Lincoln Electric Co., Cleveland, Ohio. 819 pages, 5¾ x 9 in. Flexible fabrikoid binding. 990 illustrations. Price $1.50 in the U. S., $2 elsewhere.*

To this edition, 223 pages and 289 illustrations have been added to bring the subject matter up to date. New data includes: Characteristics of the Welding Generator, Selection of Type of Joint, Insurance of Fusion-Welded Vessels, Welding Codes, Arc Cutting, Polarity of Welding Current, Horizontal Welds, Sheet-Metal Welding, Effect of Electrode Size on Welding Cost, Methods of Testing Weld Metals, 4-6 Chrome Steel, Monel Metal, Principles of Surfacing by Welding, Welded Design Begins with Standard Shapes and Plates, Plate Girders.

Older text has been thoroughly revised also.

Handbook

HANDBOOK OF CHEMISTRY & PHYSICS (21ST EDITION)—*Editor-in-Chief, Chas. D. Hodgman. Published by Chemical Rubber Publishing Co., Cleveland, Ohio. 2028 pages, 4¼ x 6¾, 2 in. thick. Indexed. Fabrikoid covers. Price $6.*

Additional tables and revisions have necessitated the addition of 175 pages to this standard text. Several mathematical tables have been rearranged, properties of plastics added, as well as several smaller tables. A special table for reducing gas volumes to standard conditions gives both the factors and their logarithms for such reductions.

The book is divided by stiff, colored-paper index inserts into five sections: Mathematical Tables; Properties and Physical Constants; General Chemical Tables; Heat, Hygrometry, Sound, Electricity and Light; Quantities & Units—Miscellaneous Tables.

National Program

WHY QUIT OUR OWN (1936). *By George N. Peek (formerly A.A.A. Administrator) with Samuel Crowther. Published by D. VanNostrand Co., Inc., 250 Fourth Ave., New York, N. Y. 353 pages, 6x9 in. Price $0.50.*

A thorough picture of a national program for farm and factory, written by Mr. Peek in the effort to discuss national prosperity on a basis of fact rather than partisanship. Part of the material appeared in six articles in "The Saturday Evening Post" under the title, "In and Out." Extremely readable.

BRIEF REVIEWS

SYDNEY (AUSTRALIA) COUNTY COUNCIL. *Annual report of the General Manager of the Sydney Council for 1935. A 60-page elaborately illustrated paper-bound report of the year on this electricity undertaking*—Free upon request.

PIPING DESIGN MANUAL—*A 70-page, 9x12-in. paper-covered book by E. A. Wert and S. Smith with G. Sinding-Larsen and George W. Petrie, Jr., collaborating. Published by Pittsburgh Piping & Equipment Co., Pittsburgh, Pa. Price, $3*—An elaborate and complete manual on figuring piping systems and details, including flexibility.

CITY OF SEATTLE, DEPARTMENT OF LIGHTING, ANNUAL REPORT FOR 1935. *A 110-page paper-covered report. Free.*

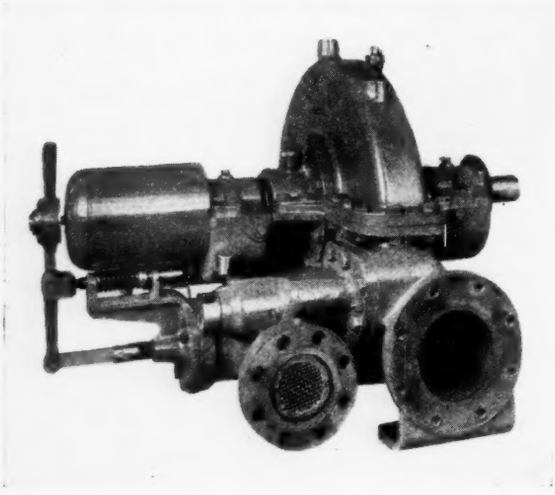
OPERATING COSTS AND REVENUES OF CANADIAN COAL-MINING DISTRICTS—*for five-year period ending Dec. 31, 1935. Copies available from Dominion Fuel Board, Motor Bldg., Sparks St., Ottawa, Ont., Canada.*

MSS STANDARD MARKING SYSTEMS FOR VALVES, FITTINGS, FLANGES AND UNIONS, SP-25-1936. *Just issued by the Manufacturers Standardization Society of the Valve and Fittings Industry. Copies from the Society, 420 Lexington Ave., New York, N. Y. Price, 50 cents*—Includes a number of new tables definitely outlining the standard methods of applying uniform markings to a wide variety of products.

THIRTEENTH ANNUAL REPORT OF THE ELECTRICITY SUPPLY COMMISSION, JOHANNESBURG, SOUTH AFRICA (for the year ended December, 1935, including a review of activities up to May 31, 1936). *A 75-page illustrated report available on application to the Commission at Electricity House, 82 Marshall St., Johannesburg, South Africa.*

POSSIBLE RECOVERY OF COAL FROM WASTE AT ILLINOIS MINES. *By Cloyde M. Smith and David R. Mitchell. Bulletin No. 285 of the Engineering Experiment Station, University of Illinois, Urbana, Ill. 44 pages, paper covers. Price, 50 cents*—Describes waste materials produced and feasibility of recovering them from coal pyrite or other valuable constituents. Some copies available free.

WHAT'S NEW IN PLANT EQUIPMENT



STEAM TURBINES

TYPE C turbines for driving general-purpose machinery on auxiliary equipment are of impulse type with one pressure and two velocity stages. Capacities from 5 to 500 hp. at speeds of 1,000 to 5,000 r.p.m. Pressures up to 650 lb. gage and total temperatures to 750 deg. F. May be operated either condensing or non-condensing, with rotation in either direction. Thoroughly dependable and free of danger of fire. Clean exhaust suitable for use in processes.

Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

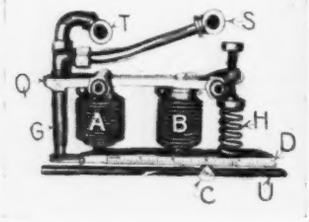
COMPOSITION BELT

Two new styles designed for unusual conditions which require some slip. Style "F" has red friction pulley surface for use where slight starting slip is desired. Style "B" has bare-back untreated duck pulley surface where greater slip is required or where slip is essential, as in winder drives.

Manhattan Rubber Mfg. Division of Raybestos-Manhattan, Inc., Passaic, N. J.

CONTROL UNIT

"ARCA" control is universal unit applicable to pressures, levels, speeds, temperatures, vacuums and flow. Has movable fulcrum for lever element which may be adjusted to suit conditions. Threaded shaft *U* turns in end bearings by means of a tool. Unit has two bellows, *A* and *B*, and flat spring *H*, latter adjustable to or from air nozzle *G*. Operated by compressed air. Flat spring gives wider throttling range where unit is operating a diaphragm-operated valve, so that openings will depend on demands. Wider range of pressure maintained from wide open to fully closed valve. Air gage in elbow *T* indicates initial air pressure, needle valve *Q*, throttled to desirable low pressure and nozzle *G* provides desired pressure on diaphragm air motor. For pressure, fulcrum *C* is placed between bellows. Higher pressure impulses on *B* requires fulcrum to be moved nearer to B. For low pressures, control bellows *A* receives impulse. Bellows which does not receive pressure impulse is compensator to prevent over-regulation or hunting. For vacuum, fulcrum *C* is at right of spring *H*, bellows *B* serving as compensator. For flow, fulcrum *C* is placed between bellows *A* and *B*. For ranges of 300 lb. and above, Bourdon tube replaces bellows *A*, with sensitivity of ½% plus or minus.

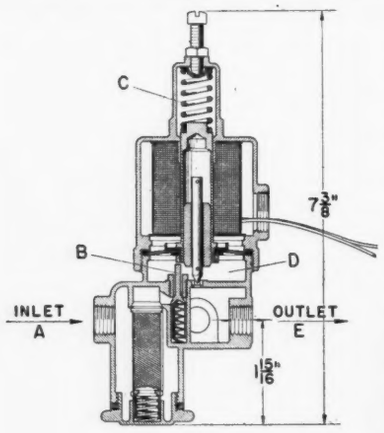


Arca Regulators, Inc., 111 Orange St., Bloomfield, N. J.

GLASS-WOOL INSULATION

CONSISTS of long-interlocked glass fibers and usable for refrigerated and heated equipment using temperatures up to 1,000 deg. F. Variety of forms in densities from 1½ lb. to 6 lb. per cu. ft. Highly efficient insulator, will not absorb fumes or moisture, fireproof, sterile, rotproof and chemically stable; fiber structure fluffs and expands instead of settling.

Armstrong Cork Products Co., Lancaster, Pa.



WATER-PRESSURE REGULATOR AND SOLENOID VALVE

FOR applications where it is necessary to control flow of water or air electrically and also necessary to control pressure at which fluid is delivered from valve. Combines functions of solenoid-operated stop valve and pressure-regulating valve. Used to control flow of water to sprays or other humidifying equipment in air conditioning. Valve includes strainer with large fine-mesh screen. Water enters at *A* when solenoid coil is energized. Plunger is drawn upward off its seat and water flows through strainer and valve body to *E*. Outlet water pressure maintained by spring setting *C*. Increase in water pressure at *D* causes diaphragm to move upward, throttling valve *B*. Diaphragm floats back and forth in response to fluctuations in supply pressure and thus maintains fixed outlet pressure. Spring *C* adjusted by screw at valve top. Outlet pressures 5 to 50 lb. or higher and maximum water pressure 100 lb. When solenoid circuit is opened, plunger drops and closes valve. Model DE. Bulletin. Sizes ¼ and ⅜ in. I.P.S.

General Sales & Products Corp., Cohoes, N. Y.

HAND COMMUTATOR SLOTTER

RETAINS swiveled joint for ease of handling with bit at any angle, but head is now circular, opposite faces having interlocking notches which are locked by a screw to hold blade at desired angle. One end of tool bit hardened and sharpened for "V" cutting, other for "U" slots. Used for beveling sharp edges of copper and fins of mica after undercutting and for smoothing burrs on copper segments. Head, stem and handle are one-piece, high-strength bronze. Handle hollow for balance, grooved for grip. Bulletin.

Ideal Commutator Dresser Co., 1025 Park Ave., Sycamore, Ill.

PIPE CLAMPS FOR STOPPING LEAKS

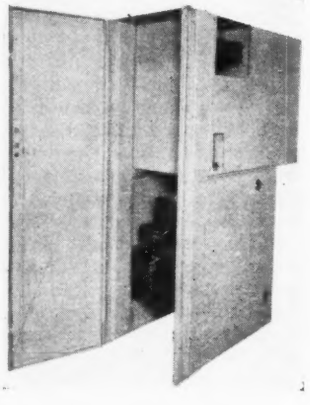
EASILY applied clamps for permanently stopping leaks in pipes, large or small, high or low pressure. Will handle pressures up to 3,000 lb. on steam, hot-water or vapor pipes going back into service or when first frost splits or bursts exposed pipes. Can be used to stop leaks in air, gas, steam, vapor, gasoline, oil, chemical, pulp, ammonia, brine and all other pipe lines.

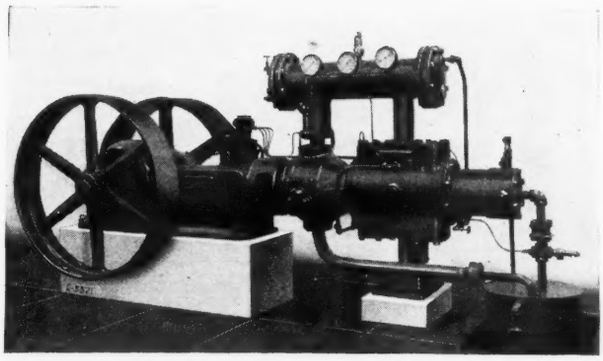
M. B. Skinner Co., 3796 W. Sample St., South Bend, Ind.

METAL-CLAD SWITCHGEAR

TYPE RA 3-phase unit, 20x40x62 to 70 in., can be mounted in banks of two or more. Self-contained; ready for installation. All live parts steel enclosed, and various elements in separate compartments with steel barriers between. 5-kv., 600-amp., 25,000- and 50,000-kva. oil-blast circuit breakers are interchangeable with other units of same rating. Breakers inserted by a small truck. Positive interlock.

Delta-Star Electric Co., Chicago, Ill.

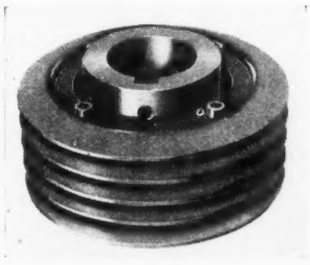




HORIZONTAL 3-STAGE COMPRESSOR

SINGLE horizontal 3-stage compressors for pressures of 750 to 2,500 lb. Compression cylinder requires only one packing box which is subjected only to moderate pressure. Can be used for high compression of air, oxygen, hydrogen, helium, special gases, refinery gas or straight natural gas. Double-row tapered roller bearings, automatic self-oiling frames with oil-tight covers, feather and ring-plate valves and inter-cooling between stages. Steam or motor drive. Bulletin L-611-B12.

Worthington Pump & Machinery Corp., Harrison, N. J.



V-BELT SHEAVE

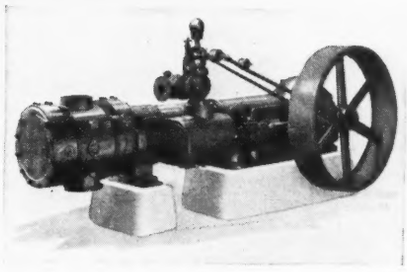
"DR" sheave consists of hub on which can be mounted rims of varying diameters and number of grooves. Rims can be mounted in four different positions so that hub can be about central or have required offset. Hub is mounted permanently and rims shifted or changed as required. Wide selection of diameters and number of grooves for "C" and "D" belts. Bulletin A-208.

Dodge Mfg. Corp., Mishawaka, Ind.

IRREGULAR CURVE

LEAD-CORE adjustable irregular curve for draftsmen has metal-impregnated exterior rubber surface against which pen or pencil slides freely. Designed with low drawing edge on one side and center drawing edge on other, providing two parallel lines at one setting if desired.

Wade Instrument Co., 2275 Brooklyn Station, Cleveland.



STEAM-DRIVEN COMPRESSOR

SINGLE-STAGE steam-driven horizontal compressor, Class WA-7, for steam pressures of 80 to 250 lb., air pressures up to 160 lb., sizes 279 to 1987 c.f.m. Steam cylinder heavily lagged. Steam valve balanced piston type with inlet pressure in the middle so that valve-rod box is sealed against exhaust only. Various controls: throttling flyball governor, fly-wheel governor, etc. Timken double-row main bearings, force-feed lubrication, special cast-alloy air-cylinder liner and laminated cushion-back valves. Bulletin A-14.

Sullivan Machinery Co., Michigan City, Ind.

SIDE-SHIELD GOGGLE

F-3105 Ful-Vue goggle has high-up end pieces, self-adjusting nose pads, 6-curve "super-armorplate" lenses and side shields. Wire-mesh screens non-corrosive and easily cleaned. Non-corrosive frame. Bulletin.

American Optical Co., Boston, Mass.

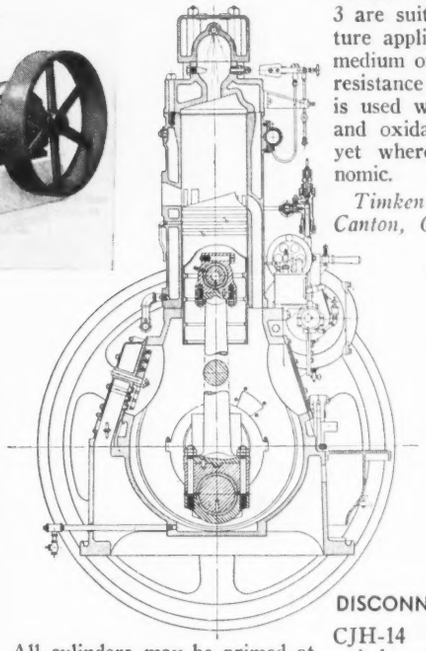
PF CORRECTION CAPACITORS

BOX-TYPE power-factor correction capacitors are compact, flexible, easy to install and have improved mechanical and electrical features. Can be mounted on ceiling, wall or floor in units or groups to 100 kva. Bulletin.

Power Factor Division, Cornell-Dubilier Corp., So. Plainfield, N. J.

2-CYCLE OIL ENGINE

TYPE M 2-cycle oil engine is made in three cylinder sizes, 10 x 14 at 327 r.p.m., 12½ x 18 at 277 r.p.m., and 14 x 18 at 277 r.p.m., giving rated horsepowers varying from 30 to 360, with one to four cylinders for the two smaller sizes and one to six for the larger. Forged connected rods, automatic governor and injection pump in one unit, with separate pumps for each cylinder actuated by individual tapered cams and rollers.



All cylinders may be primed at any position. Semi-steel cylinder, water - jacketed entire length. Outer wall curved in section for even expansion. Cast-steel cylinder head with large water space, dowelled to cylinder. Separate wire gaskets. Bulletin 336.

Anderson Engine & Foundry Co., Anderson, Ind.

BELT LACING

"TEK-LACE" non-metallic belt lacing for flat belts or V-belts. Only 0.055 in. in diameter, has tensile strength of 100 lb., more than 50% stronger than Federal specifications for rawhide ¾ in. wide and ⅛ in. thick. A 3-in. belt fastened with this lace has a tensile strength of 2,000 lb. at the joint. Holes for it are not cut but pierced.

Sudbury Laboratory, P.O. Box 940, South Sudbury, Mass.

CHROME STEEL ELECTRODE

"CHROMEWELD 4-6" electrode welds 4-6% chromium steels used for resistance to crude-oil corrosion at high temperatures and pressures. Steels welded with this electrode, which contains molybdenum, can be soft-annealed to physical properties similar to those of mild carbon steel. Three sizes, ⅛, $\frac{5}{32}$ and $\frac{3}{16}$ in.

Lincoln Electric Co., Cleveland, Ohio.

HIGH-TEMPERATURE STEEL

SICROMO 1, 2, 3 and 5 high-temperature steels contain 0.50% molybdenum to increase creep strength. High silicon content develops oxidation resistance, and chromium in proportion to numbers of alloy provides corrosion resistance. Nos. 1, 2 and 3 are suitable in high-temperature applications where low to medium oxidation and corrosion resistance are required. No. 5 is used where severe corrosion and oxidation are encountered, yet where cost must be economic.

Timken Steel & Tube Co., Canton, Ohio.

DISCONNECT SWITCH

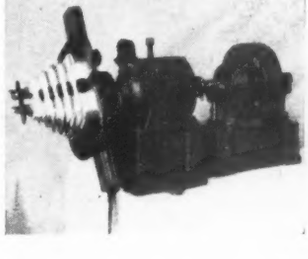
CJH-14 indoor disconnecting switches may be mounted either on flat surfaces or on pipe. Copper tongue-type contacts bridged by floating 2-section blade with lock automatically engaging when blade is closed and releasing when blade is opened. Terminal lugs are clamping, solderless type. Ratings 7.5 to 34.5 kv.

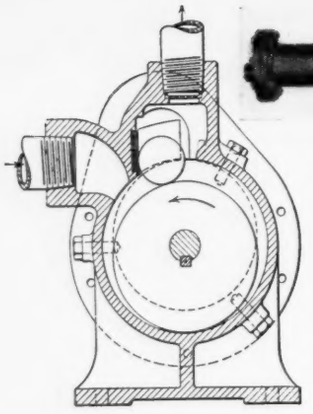
Delta-Star Electric Co., Chicago, Ill.

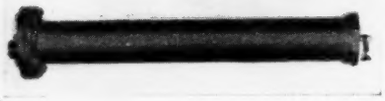
CONCENTRIC COIL-WINDING HEAD

THIS head winds single-phase motor coils in gangs or groups up to six in a nest in all sizes and shapes, connected in series so that they can be removed together and inserted in stator without series soldering.

Ideal Commutator Dresser Co., 1025 Park Ave., Sycamore, Ill.







of 75 cu.ft. or less. Air inlet and outlet are both in top cap so that condenser body can be removed easily. Average pad life three months. 4 ft. 8 in. long, tube diameter 6 in., 2-in. pipe thread on inlet and outlet tubes, net weight 140 lb.

The DeVilbiss Co., Toledo, Ohio.

ROTARY PUMPS

HIGH over-all efficiency because of freedom from excessive friction, as high as 80 to 90%. Rotor and cylinder have rolling action. Unit is self-priming up to suction lift of 22 ft. and will produce, on water, a dead-end vacuum of 29 in. at 30-in. barometer. Very quiet. Displacement mechanism consists of rotor and a free-rolling roller or abutment on top of rotor. Roller provides positive seal between intake and discharge ports, turns against non-metallic insert and compensates for wear. Rotor, mounted eccentrically on shaft, has extended cut-off surface at high points which closes two ports at completion of each discharge, thus preventing back leak. Oilless bearings. Special non-tightened packing. Pressures up to 100 lb. on non-lubricant liquids at 275 to 300 r.p.m. Rotation clockwise looking from shaft end. Intake port at side and discharge port at top. Either all iron or all bronze.

Anderson Rotary Pump Co., 120 Liberty St., New York, N. Y.

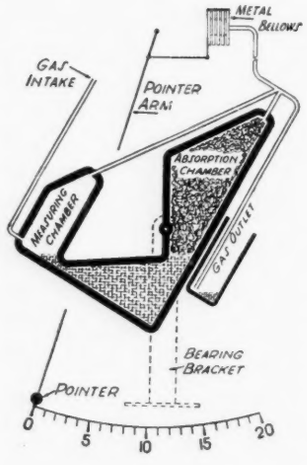
SOFT-FACED HAMMERS

TIPS are tough, amber-colored composition that does not chip, shatter, or break. Old tips may be turned loose with pipe wrench and new tip pressed on to steel center body. Hickory handle. Three weights: 1½ oz., ½ lb., and 1 lb.

Bonney Forge & Tool Works, Allentown, Pa.

AIR-LINE CONDENSER

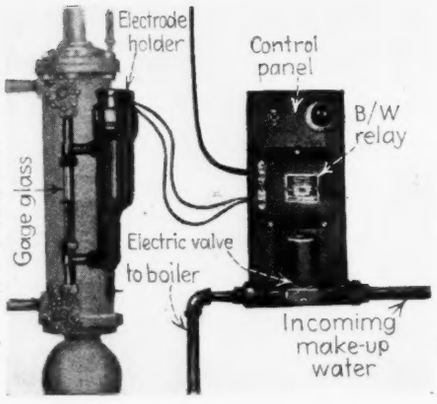
TYPE HP-504-2 heavy-duty condenser removes oil and water from air lines by baffle arrangement and pair of filter pads. Maximum air delivery volume



AUTOMATIC ORSAT

"ORSATOMAT" analyzes its flue-gas sample in 20 seconds by simply operating a lever. Entire action automatic. No valves and no manual leveling or measuring. Results indicated by pointer movement on large scale. Rotatable analyzing body contains measuring and absorption chambers and charged with mercury and absorbing chemical, metallic bellows and linkage for moving pointer, aspirator bulb and necessary rubber tubing, all in pressed steel case of non-tipping design with carrying handle. Sample is taken in while instrument is in position illustrated. Automatic valve allows gas to bypass so that it is always measured at atmospheric pressure. Rod is then pushed down to analyzing position, sealing automatic valve and rotating analyzing body, causing mercury to flow to a new position. Liquid absorbing chemical floats on top of mercury and gas sample is displaced from measuring chamber into absorption chamber where it is forced into intimate contact with steel wool saturated with absorbing chemical. Absorption of CO_2 causes shrinkage in volume of sample, creating a vacuum transmitted to pointer by metallic bellows and read directly on scale as per cent CO_2. Absorbing chemical retains strength for long period.

Hays Corp., Michigan City, Ind.



BOILER-WATER LEVEL CONTROL

FOR boilers up to 1,000 sq. ft. with pressures of 20 to 150 lb., this water-level control has an electrode holder mounted on water column in connection with gage glass. Electrode holder has long and short electrodes connected to an electric relay. When water level drops below long electrode, relay opens electric valve until water rises to level of shorter electrode, when current is cut off. No floats, stuffing boxes, generators or thermostats are used. Electrodes adjustable to give desired water level and range. Circular.

The Johnson Corp., Three Rivers, Mich.

SAFETY BELT

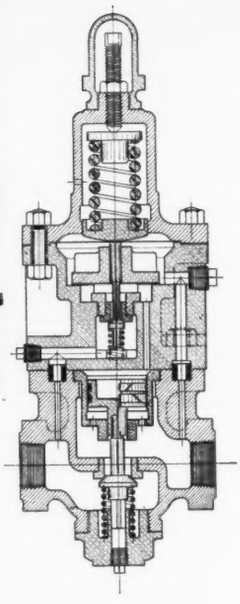
"HY-TENSIL" safety belt material is a gum-impregnated, laminated, moisture-proof fabric having 6,500 lb., tensile strength uniformly through its length. Moisture-proof and highly resistant to snagging and cutting, and has high dielectric strength.

American Allsafe Co., Inc., 210 Franklin St., Buffalo, N. Y.

2-STAGE AIR-COOLED COMPRESSORS

COMPACT, self-contained, 3- and 6-cyl., vertical-angle, 2-stage air-cooled compressors, having capacities from 142 to 445 c.f.m. 3-cyl. unit has two low-pressure cylinders opposite each other at an angle, with a high-pressure cylinder set vertically between. 6-cyl. unit is set in same manner, with two cylinders side by side in each position. Units may have Worthington Multi-V-Drive, direct-connected to motor through flexible coupling, or with motor mounted directly on crankshaft end. Force-feed lubrication. Oil cooler and filter. Suction and discharge valves in separate compartments, allowing removal without disturbing pipe connections. Crankcase fitted with large cover plates. Bulletin L-620-B16.

Worthington Pump & Machinery Corp., Harrison, N. J.



PILOT OPERATED PRESSURE-REDUCING VALVES

STYLE "A", auxiliary or pilot operated, for steam or air, is self-contained, and will reduce high initial or supply pressure to any reduced or delivery pressure from 1 lb. up to within about 20 lb. of initial pressure. Variations in initial pressure do not interfere with positive operation when within valve capacity at any given pressure differential and will maintain desired reduced or delivery pressure until a change is made in adjustment or dirt or wear interfere with valve operation. Particularly suitable where sudden variations in demand or load occur and designed for control of steam or air pressures in intermittent and dead-end service where positive and reliable regulation is required. Changed from high reduced pressure to low reduced pressure by changing regulating spring and diaphragm. Standard construction up to 250 lb. and 500 deg. F. Sizes ½ and ¾ in. of bronze, 1 in. and larger cast iron. Internal parts bronze, piston rings cast iron for up to 1,000 deg. F. Springs are steel. For pressures to 400 lb. and superheated steam of 750 deg. F. total temperature, bodies are extra-heavy cast steel with stainless steel internal parts, except for ½ and ¾-in. bodies, which are special alloy.

Schade Mfg. Co., 2527 N. Bodine St., Philadelphia, Pa.

ARC WELDER

HANSEN "Smootharc" welders have single current control, self-excitation and internal stabilization. Two styles, vertically mounted in 75, 100, and 150-amp. capacities, horizontally mounted in 200, 300, 400, and 600-amp. Compact and streamlined for portability.

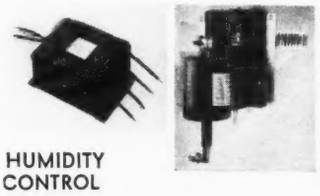
Single current control by patented design of shifting generator brushes with a micrometer screw. Self-excited by set of auxiliary brushes ahead of main brushes and connected to auxiliary shunt winding. No extra commutator needed. Interpole winding extended to main pole shoes acts as stabilizer. Single control panel built into housing. Rolled steel, arc-welded construction. All steel parts annealed to improve magnetic field for generator fluxes.

Harnischfeger Corp., Milwaukee, Wis.

SIGNALING TRANSFORMERS

For general application where low-voltage power supply is required. Range of volt-ampere capacities and secondary voltage taps. Core and windings specially impregnated and sealed in heavy steel case to make unit moisture-proof. Designed to be connected to power lines continuously with low power loss.

Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.



HUMIDITY CONTROL

This combination of Supreme solenoid water valve mounted on Friez insertion humidistat incorporates insertion humidistat often preferred for installation in "cold-air returns" and cabinet-type conditioners. Electric valve especially designed for humidity work. Has cast-iron case with terminal chamber for BX connections. Descriptive leaflet No. 3820. Unit assembled by:

Supreme Electric Products Corp., Rochester, N. Y.

DIRECTIONAL DISTANCE RELAY

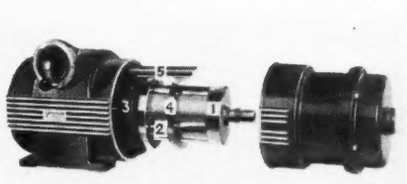
Type GCX12A high-speed, 3-phase directional distance relay combines all functions of three commonly required devices in one relay assembled and tested, ready for installation. Unit consists of three starting elements, three resistance units, and a timing unit, also two instantaneous overcurrent units, one for each of two phases, to prevent tripping on fault currents less than their setting. Units connected with coils in series, with current windings of starting units and their contacts in series with the main tripping contacts. Each overcurrent unit has calibrated settings of 4, 7 and 10 amp. Operating time on phase-to-phase faults in proximity to the relay will range from 1 to 1½ cycles, with corresponding currents of 20 to 10 amp. Remote faults increase time, relay in case 16 x 20 with 18 x 22 mounting flange, 7 in. deep. 6-in. extension through and back of panel.

General Electric Co., Schenectady, N. Y.

LOW-CAPACITY AIR REGULATOR

Type HFS for sensitive regulation of air pressures below 30 lb. Has 4-in. diameter diaphragm. Variation only 1 oz. for each 10-lb. variation of main-line pressure.

The DeVilbiss Co., Toledo, Ohio.



VARIABLE-SPEED TRANSMISSION

Compactly housed transmission is about motor size and gives from ½ motor speed down to zero and reverse, with one turn of control wheel. Self-contained, runs in oil and has only five major parts. Power is commonly taken from constant-speed motor, the shaft of which is connected to carrier (1), latter therefore rotating at motor speed. This carrier supports three taper rollers (2) kept in intimate contact under pressure with a non-rotating ring (4) and thus must turn at motor speed times ratio of ring and roller diameters at point of contact.

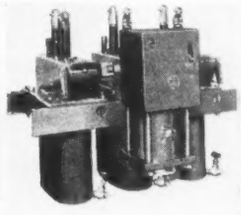
Three rollers carry planet pinions which mesh with internal gear (3), the latter being connected to output end of unit, thus providing a step-down ratio combined with speed variation, obtained by moving ring (4) along taper rollers. Internal gear is non-metallic, transmission bi-directional and can be driven from output end. Motor can be built in, connected to transmission by a flexible coupling, or unit may be driven from lineshaft or other power shafts. Geared heads can be incorporated at output end. Geared head provides reduction up to 7 to 1 or step-up as high as 1 to 4. In latter case top speed can be as high as twice motor speed. With reduction gearing, full motor power can be developed at a top speed of 60 r.p.m. Can be controlled by remote or automatic unit by pressure or tension device, cam, pilot motor, Selsyn or other commonly used methods. Three standard sizes with range of capacity up to 7½ hp. and two speed ranges, normal and extreme. Both units with or without geared heads.

Graham Transmissions, Springfield, Vt.

OIL CIRCUIT BREAKER

For interrupting from 100,000 to 250,000 kva. at 15,000 volts with a separate tank for each phase, these Type FK-158A, B and C oil-blast breakers are available in 1, 2, 3 and 4-pole units, with trip-free electrically or manually operated mechanisms. Elliptical reinforced steel-plate tank. Herkolite bushings. Type 158A has main contacts of silver-to-silver line pressure type with butt-type copper facing contacts, while Types B and C have main contacts of wedge-and-finger type. Available for mounting on fabricated steel framework or in steel or masonry cells.

General Electric Co., Schenectady, N. Y.



PUMPING UNITS

Integrated rotary pumping units have pump on 3-point support base designed to take a high-speed NEMA-frame electric motor, connected to pump through enclosed gears running in oil. Bypass and strainer are also provided. Single units with capacities from 35 to 700 g.p.m. and twin units with capacities of 50 to 100 g.p.m. Full-capacity bypass with no end thrust on working parts. Flange connections for ease in lining up piping. Fully enclosed and self-lubricated drive. Full flow strainer, easy to clean. Readily replaceable buckets. Bulletin 1U300.

Blackmer Pump Co., Grand Rapids, Mich.

MANUAL OPERATING LEVER

Type HC-2 operating lever has been designed for use on manually-operated type FK-42 oil-blast circuit breakers for panel or remote mounting. This lever is trip-free throughout its entire stroke and has toggles so designed that breakers equipped with it are easy to close. Trip coils interchangeable for all breakers using Types HC-2 and HA-2 levers.

General Electric Co., Schenectady, N. Y.

TRANSFER CONTROL SWITCHES

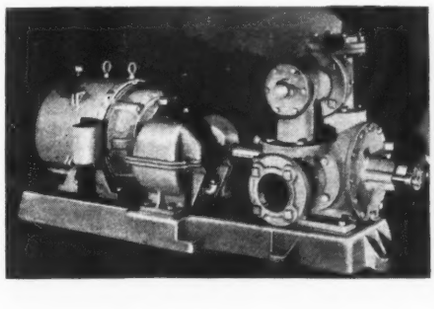
Type SB-1 switches now have electrically separate stationary contacts, large escutcheon, water and oil-tight housing, and removable handles. Water in oil-tight case is in non-corrodible metal housing with suitable gasket. Three sizes, from 1 to 4 stages, for 5 to 8 stages, and for from 9 to 12 stages. All can be adapted for use in explosive atmospheres. Special machined metal insert in molded-compound handle makes all types of SB-1 switch handles removable and non-interchangeable. Key and slot to prevent removal of handle, unless switch is in proper position.

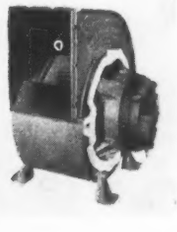
General Electric Co., Schenectady, N. Y.

DRIVE BRACKET FOR BLOWER

Motor drive bracket for direct-connected blowers maintains high quietness of operation. Standard motor bracket is mounted on second floating bracket insulated from blower housing, to which it is secured by flexible rubber cushions. Floating drive bracket shown on photograph by white finish. No metal-to-metal contact. Used on Ilg Type B or Type BC direct-connected universal blowers.

Ilg Electric Ventilating Co., 2850 North Crawford Ave., Chicago, Ill.





UNIT HEATERS

SERIES of special color finishes, including Spanish ivory, heather brown, silver, Pacific blue, etc., now available on these unit heaters. It is a special baked crackle finish.

Ilg Electric Ventilating Co., 2850 North Crawford Ave., Chicago, Ill.

WELDERS

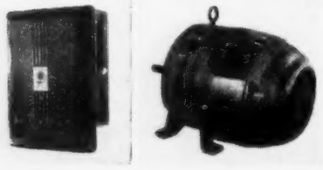
NOEL "Speedarc" Welders have unity power factor at full load and leading power factor up to 40% at no load for supplying power factor correction. Unit claimed to have 10 to 13% higher over-all efficiency than average welder. High-speed, lower operating cost, constant settings, duel control, etc. Steel construction. Sizes from 125 to 400 amp., with truck or stationary mounting. Control centralized on top of unit. Circular 911.

Ideal Electrical & Mfg. Co., Mansfield, Ohio.

NON-REVERSING LINESTARTERS

DE-ION non-reversing linestarters in four sizes from 25 to 150 amp. used for across-the-line starting of squirrel-cage induction motors and as primary switches for wound-rotor induction motors, particularly where control is desired from pushbutton or other pilot device. Compact, accessible, dependable. Vertical operation of magnets to prevent accidental closing of contacts due to mechanical shock or tilting. Bimetal thermal overload relay. Contact and relay mounted on steel panel with no back-of-panel wiring. Thus can be used for built-in applications.

Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.



FAN-COOLED MOTORS

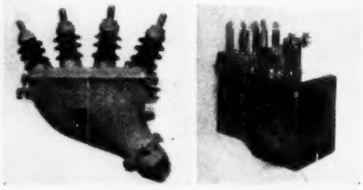
TYPE SK explosion-tested, fan-cooled, totally enclosed, d.c. motors in sizes from 5 to 75 hp. and 115, 230 and 550 volts. Brushes and commutator accessible. Fan on commutator so that gear case or pulley will not restrict ventilation. Built to withstand internal explosion of gas or coal dust without injury to equipment and without emitting flames or sparks. Special double-walled front bracket with four screw-type handle covers removable for adjustment of brushes and commutator.

Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

7500-VOLT, 500-AMP. CABLE TERMINATOR

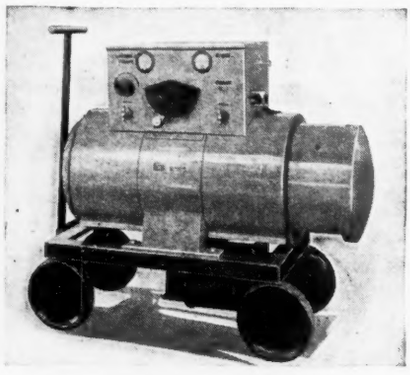
CAP nut and cover gaskets confined in a recess protected from weather. Cap nut compresses its gasket a definite amount, then makes direct electrical contact with bronze cap cemented to porcelain. Constant pressure on gasket and stud threads assured by laminated spring washer integral with stud. Vertical soldering holes in stud connector. Porcelain bushings cemented into bronze cover for weather-proofing. Body hot galvanized.

Delta-Star Electric Co., Chicago, Ill.



INDOOR OIL CIRCUIT BREAKERS

TYPE F-122 solenoid-operated oil circuit breakers rated at 25,000 kva. manually and electrically operated up to 600 amp., 7,500 volts, and 800 amp. 2,500 volts, 2- and 3-pole, single-throw. Operating levers inside breaker chamber away from live contact terminals. May be arranged for panel or panel frame mounting direct control; for wall, pipe, or structural-steel frame mounting for remote control. Electrically operated breakers may be arranged for wall, pipe or structural-steel frame mounting, remote control. Type SAF-2 solenoid-operated mechanism is separate but mounted directly on breaker.



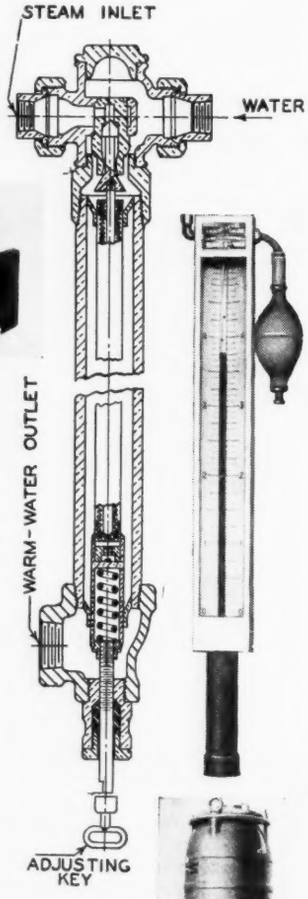
Unit is mechanically full automatic, thus it is impossible to hold breaker closed against an overload on line.

Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

STEAM AND WATER MIXER

COMPACT and self-operated mixing valve produces hot water at any desired temperature automatically directly at point of use by mixing steam and water in proportions required. Incorporates 3-way valve, water injector and temperature regulator all in one unit. Nozzle-type injectors insure silent operation. Small sizes use single seated valves, large sizes, double seated. Frequently units make unnecessary the use of separate small water heaters.

Sarco Co., Inc., 183 Madison Ave., New York, N. Y.



VERTICAL TURBINE PUMP

SIMPLE, compact vertical unit for dewatering mines, quarries, etc., ranging in capacity to 10,000 g.p.m. Can be used either as fixed or portable unit. Waterproof motor at top, with vertical hollow shaft. Grease lubricated; easily accessible stuffing box. Inlet vane grease-packed. Hard bronze impellers. Bowls containing discharge vanes and discharge connection are cast iron. Basket strainer at inlet. Total dynamic heads, 20, 30, 40, 50 and 60 ft., motor sizes 5 to 250 hp., 870 to 1750 r.p.m. Bulletin W-450-B25.

Worthington Pump & Machinery Corp., Harrison, N. J.

ATMOSPHERIC PRESSURE-TANK GAGE

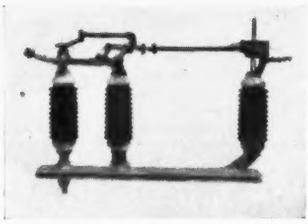
AIR-ACTUATED unit using mercury as measuring medium and non-evaporating red oil in a glass tube to indicate. Mercury chamber at bottom is concentric U-tube. Top of outer chamber of this tube is connected directly with copper tube connection on left side of gage top. Copper tubing used from this point to bottom of tank being measured. Bulb at top right-hand side serves as air pump which connects with small tube that passes down behind indicating dial to bottom of outer chamber of U-tube. Air pumped in, bubbles through mercury of this chamber and out through connection at top left-hand side of gage in tank. Air thus trapped by mercury can escape only through opening of copper tubing at bottom of tank being measured. Air pressure cannot be increased by continuous pumping. Pressure will be equal to air pressure of liquid in tank being measured. This pressure also contacts mercury of outer U-tube chamber depressing it and up an inner tube in connection with indicating glass. Inner tube of mercury chamber has red oil up to point of oil indication. When liquid measured is above required position of indicator, pumping air is not necessary as liquid may be piped directly to instrument.

T. W. McNeill Engrg. Equipt. Co., 4057 Van Buren St., Chicago, Ill.

MOTOR-MOUNTED BRAKE

TOTALLY enclosed, automatic solenoid brake integral with the motor from fractional to 10 hp. (at 3,600 r.p.m.) supplied already mounted, on any motor, from the motor manufacturer. Self-contained and better-looking, dependable, ease of adjustment, smooth operation. Rotating member, a single, heavy, molded disk. Enclosing case protects it from dirt and mechanical injury. Suitable for a.c. or d.c. and available with dust tight, weatherproof and watertight enclosures.

Cutler-Hammer, Inc., 294 N. Twelfth St., Milwaukee, Wis.



UNIVERSAL VERTICAL-BREAK DISCONNECT

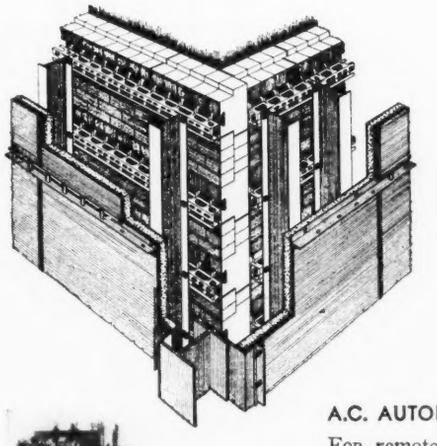
WITH latest type post insulators having centilever strengths of 2,000 lb., torsional of 12,000-in.-lb., this Type AAB-139, 34.5-kv., 600-amp., switch mounts in upright, vertical or inverted position. Self-aligning contacts are medium-pressure type, wiping clean with each operation, yet fully closed when switch is open, thus excluding dirt, dust or soot. Contacts of large areas give effective heat dissipation under short circuit.

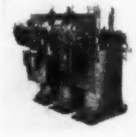
Delta Star Electric Co., Chicago, Ill.

SUPPORTED FURNACE WALL

SECTIONALIZED wall, each section being built totally independent of any other. Weight of all refractories transferred to supporting steel framework. All supporting metal is entirely in back of refractory, where it can be cooled by circulating the air. Joints are broken to prevent infiltration of air. Refractory belt spacing can be varied simply by increasing or decreasing number of courses of standard firebrick. This flexibility reduces the number of casting and tile shapes required.

Geo. P. Reintjes Co., 2517 Jefferson St., Kansas City, Mo.





INDOOR OIL BREAKERS

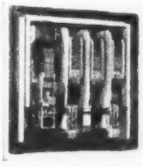
INDOOR station-type breaker Type FZ-210 has interrupting devices called "Ruptors" to give quick clearing of short circuits along with low arc energy, low pressure and minimum oil deterioration. Inclosed, low-inertia, high-speed mechanism, internal oil-type shock absorbers, silverplated contacts, oil and gas separators and Bakelain bushings. Interrupting rating 250,000 kva., for 600, 1,200 and 2,000 amp., at 15 kv. Arranged for cell mounting (truck or platen) or for mounting on framework.

Condit Electrical Mfg. Corp., Boston, Mass.

AIR CIRCUIT BREAKER

TYPE AE-1 air circuit breaker is adapted to industrial and central station auxiliary service, or for heavy duty where many opening and closing operations are required. 20,000-amp. interrupting rating and for operation on circuits of 250 volts and 600 volts a.c. at 15 to 600 amp. Standard arrangement is inclosed breaker with pullbox for mounting on wall or behind switchboard panel; without pullbox for mounting on switchboard front. Main contacts silver-to-silver; arcing contacts special alloy. Double and triple-pole units are available. Selected overload differentiates between overload and short circuits, time delay being provided up to six to ten times calibration setting and instantaneous above that. Mechanism electrically operated, trip-free, and latched-in with solenoid suitable for either a.c. or d.c., depending on rating. With pullbox 19 x 21 x 21 in.; without, 9-in. depth.

General Electric Co., Schenectady, N. Y.



A.C. AUTOMATIC STARTER

FOR remote operation of 7½ to 25-hp. a.c. motors, this starter is accessible for inspection, has parts arranged for quick replacement, vertical closing action and compactness. Replaceable units include magnet assembly, stationary or moving contacts and thermal relays. Called Type T, Class 8536. It is a line-voltage type, can be used to start polyphase squirrel-cage motors directly across line at full voltage where application permits. Sizes include units for motors from 7½ hp. at 110 volts to 25 hp., 440 volts, 550 volts and 600 volts. Units for single-phase motors from 3 hp. at 110 volts to 7½ hp. at 220. Illustrated is a close-up view of the mechanism removed from cabinet with its suporting plate. Open for inspection or access and with one moving contact slipped out of its clips. Double-break contacts are silver, and contact blocks arranged for additional auxiliary contacts for electrical interlocking or signal operation. Two or more push-button stations, limit switches or other mechanisms can be used, and two or more units can be interlocked electrically for sequence operation. Liquid-level, pressure, and heat-regulating devices can be supplied with a starter and automatic motor control. Bulletin 132.

Square-D Co., Industrial Controller Division, Milwaukee, Wis.

OXY-ACETYLENE REGULATORS

THREE units for oxygen and acetylene regulation, Oxweld R-66 oxygen regulator, Type R-65 specifically for broad range of cutting operations, and Type R-66 acetylene regulators to be used in combination with either R-64 or R-65. R-64 is suitable for all welding and cutting operations up to a required oxygen pressure of 75 lb. per sq. in. Type R-65 is designed for cutting with pressures up to 200 lb. per sq. in. oxygen, but can also be used for welding at low gas pressures if necessary. All have stem-operated valves which close with instead of against incoming pressure, sensitive rubber diaphragm, self-contained first-stage valves, pressure-forged bodies and caps. 3-spoke pressure-adjusting screw. Standard hose connection outlet.

Linde Air Products Co., 30 East 42d St., New York, N. Y.

FORGED-STEEL TRAP

No. 312 is a small, relatively low-priced trap to take care of high-pressure drips up to 450-lb. gage. Either ½ or ¾-in. screwed or flanged connections. Inverted-bucket and free-floating lever operating principles. Only moving parts are bucket and valve-lever assembly. All interior mechanism stainless steel; valves and seats heat-treated. Body and cap forged of SAE .25 to .30 steel; bolts and nuts Supertemp steel. Wt. 30 lb., 6¾-in. diam., 10¼ in. high. At 450 lb., continuous discharge capacity is 2,500 lb. hot condensate per hr.

Armstrong Machine Works, 712 Maple St., Three Rivers, Mich.

LOW-TEMPERATURE BRAZING ALLOY

ADDED "Sil-Fos" strip thickness, 0.005 in. in widths of ¼ in. or more. To wire-form "Easy-Flo" has been added 3/64-in. diam., and four new gages of strip: 0.020 in., 0.010, 0.005 and 0.003 in., all ¼ in. or more in width. For special applications, additional forms and sizes, including washers, circles, rings and filed or powdered forms.

Handy & Harman, 82 Fulton St., New York, N. Y.

REMOTE-READING GAGE

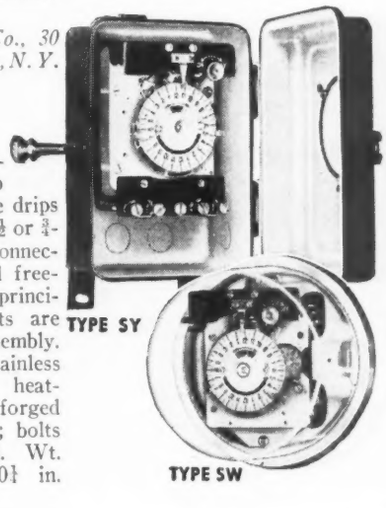
"EYE-HYE" shows precise level of boiler water as bright green liquid, sharply illuminated. Brings reading down around corners, girders, piping, etc., without difficulty in any reasonable distance.

Reliance Gauge Column Co., Cleveland, Ohio.

TIME SWITCHES

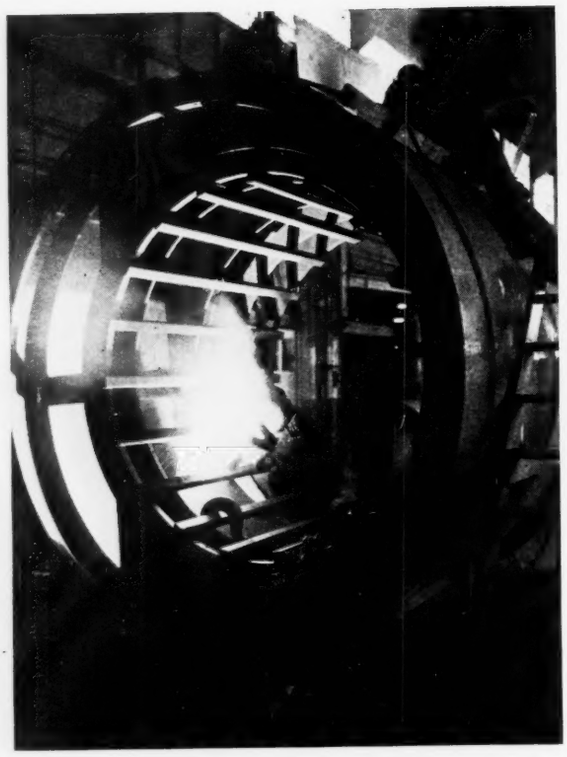
SYNCHRONOUS-MOTOR "Sauter" switches in 4- or 30-amp. capacity for 110 or 220 volts. Both will control almost any type of a.c. circuit operated on a predetermined-time basis. Hardened-steel pinions. Plain or astronomic dials, according to need. Vernier time adjustments make it possible to set switches within ½ min. SW, designed for mounting in standard meter socket, is frequently used for off-peak water heating and 2-rate metering control. Also suited for other uses similar to SY, which has all-metal housing.

R. W. Cramer Co., 67 Irving Place, New York, N. Y.



TYPE SY

TYPE SW



GAS-TIGHT WELDED GENERATOR FRAME

This will be part of a 58,000-kva. hydrogen-cooled turbo-generator. The section shown is one-half of the frame and measures 138 in. in diameter and 104 in. long. Weighing almost 20 tons, it is entirely arc-welded and is being fabricated in the Westinghouse East Pittsburgh shops. Welds are tested for tightness at a pressure of 80 lb. per sq. in.

POWER LINES

A.S.M.E. ANNUAL MEETING PROGRAM

INCLUDED in the program of the annual meeting of the American Society of Mechanical Engineers are, as usual, many sessions and events of interest to power engineers. Except where otherwise noted, all sessions will be held in the Engineering Societies Building, 29 West 39th St., New York, over the period Nov. 30 to Dec. 4.

MONDAY, NOV. 30

8:00 p.m. Power Session

Domestic Oil Burners, by A. H. Senner.

Steamotive—A Complete Generating Unit, Its Development and Test, by E. G. Bailey, A. R. S. Smith, and P. S. Dickey.

TUESDAY, DEC. 1

9:30 a.m. Heat Transfer

Problems in the Collection and Evaluation of Data for Design of Steam-Generating Units, by B. J. Cross.

The Thermal Conductivity of Liquids, by J. F. Downie Smith.

Temperature and Combustion Rates in Fuel Beds, by M. A. Mayers (to be presented by title).

Discussion of Heat-Transfer Activities.

12:30 p.m. Luncheon

Discussion: Activities of Petroleum Division.

12:30 p.m. Luncheon

Lubrication Research and Application.

2:00 p.m. Cinder Catchers

Fuels Panel Discussion. Discussers: W. G. Christy, H. F. Johnstone, C. W. d'Hedberg, Ollison Craig, H. F. Hagen, L. C. Whiton, Jr., Paul Thompson, J. J. Grob, H. P. Hardie, C. S. Messler, M. D. Engle, J. H. Leitch, H. B. Reynolds, Stanley Brown.

2:00 p.m. Fluid Flow and Aerodynamics

The Effect of Installation on the Coefficients of Venturi Meters, by W. S. Pardoe.

Extended Information on Orifice Coefficients, by S. R. Beitler.

Square-Edge Inlet and Discharge Orifices for Measuring Air Volumes in the Testing of Fans and Blowers, by L. S. Marks.

The Modified I.S.A. Orifice with Free Discharge, by M. P. O'Brien and R. G. Folsom.

Westinghouse Ninetieth Anniversary

4:30 p.m. Commemoration

The Engineering Achievements of George Westinghouse—a discussion of his former associates.

8:00 p.m. Honors Night

Towne Lecture, by Dr. James Rowland Angell, President of Yale University.

WEDNESDAY, DEC. 2

9:30 a.m. Oil and Gas Power

Supercharging of Internal-Combustion Engines with Blowers Driven by Exhaust-Gas Turbines, by A. Buchi, Winterthur, Switzerland

Diesel-Engine Operating Maintenance and Outage Data, by Lee Schneitter

Discussion of Oil-Engine Cost-Data Report

9:30 a.m. Power

Undercooling in Steam Nozzles, by J. T. Rettaliata.

Tests of a Large Surface Condenser at Widely Varying Temperatures, Velocities of Inlet Water, and Loads, by G. H. Van Hengel

2:00 p.m. Power and Applied Mechanics

Superposed Turbine-Regulation Problems, by A. F. Schwendner and A. A. Luoma.

Turbine Supervisory Instruments and Records, by J. L. Roberts and C. D. Greentree.

Supervising Instruments for 165,000-Kw. Turbine at Richmond Station, H. Steen-Johnsen.

2:00 p.m. Machinery and Springs

Discussion of Spring Problems to Include Rubber Springs, Helical Springs and Spring Material.

Bearing Oil-Ring Performance by *R. Baudry and L. M. Tichvinsky.*

Quieting Machinery with demonstrations by E. J. Abbott.

2:00 p.m. Hydraulics

The Cooperative Hydraulic Machinery Laboratory at the California Institute of Technology, by R. T. Knapp.

Experimental Determination of the Flow Characteristics in the Volute of Centrifugal Pumps, by R. C. Binder and R. T. Knapp.

6:30 p.m.

Annual Dinner, Astor Hotel.
Thurston Lecture.

THURSDAY, DEC. 3

9:30 a.m. Thermodynamics

(Jointly with A.S.R.E.)

Review of Existing Psychometric Data With Relation to Practical Engineering Problems, by W. H. Carrier and C. O. Mackey.

Method of Computing Thermal Properties of Oxygen Nitrogen, and Derivation of a New Equation of State Therefore, by W. L. DeBaufre and T. A. Filipi (to be presented by title).

Leakage of Gases Through Narrow Channels, by A. Egli (to be presented by title).

9:30 a.m. Power

Physical-Property Uniformity in Valve-Body Steel Castings, by A. E. White, C. L. Clark and S. Crocker.

Unique Design Features and Operating Experiences at the Port Washington Power Plant, by F. L. Dornbrook.

Corrosion-Resistant Metals

9:30 a.m. Symposium—I

Introduction to Corrosion-Resistant Metals, by F. H. Speller.

Aluminum and Its Alloys, by E. H. Dix, Jr., and R. B. Mears.

Construction and Use of Lead Equipment, by G. O. Hiers.

12:30 p.m. Luncheon

Maintenance: Discussion of Organization and Management of Maintenance, J. A. Jacobs, Chairman; Discussers: W. C. Zinck, J. I. Thompson, A. Vaksdal, W. O. Larson, A. E. Windle.

2:00 p.m. Boiler Feedwater

Discussion of Boiler-Feedwater Problems to Include Progress Report on Embrittlement and Dissolved Oxygen Determination.

Reactions of Sodium Sulphite under Boiler Operating Conditions, by Prof. F. G. Straub.

Corrosion-Resisting Metal

8:00 p.m. Symposium—III

Corrosion-Resistant Steel, by J. H. Critchett.
Nickel and Nickel-Base Alloys, by F. L. LaQue.

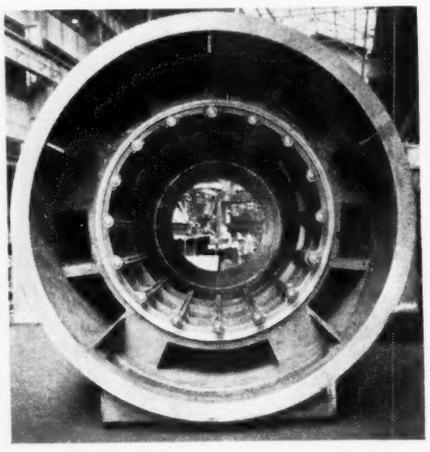
8:00 p.m. Turbine History

The Steam Turbine in the United States.

I—*Development by the Westinghouse Machine Company*, by E. E. Keller and F. Hodgkinson.

II—*Early Development by the Allis-Chalmers Manufacturing Co.*, by A. G. Christie.

III—*A Brief History of Steam-Turbine Development by the General Electric Co.*, by E. L. Robinson.



THROUGH A GENERATOR

A workman in the G. E. Schenectady shops seen through the stationary-armature frame of a 25,000-kw. hydrogen-cooled turbo-generator under construction for Dayton Power & Light Co.

Refrigerating Engineers Meet Dec. 2-3-4 in New York City

The 32nd Annual Meeting of The American Society of Refrigerating Engineers will be held Dec. 2-4 at the Hotel Pennsylvania, New York. All meetings, except the joint meeting with the A. S. M. E. on the morning of Dec. 3, will be held in the Hotel Pennsylvania.

An innovation will be short informal talks by leaders in the refrigeration and air conditioning field. Gardner Poole of Frosted Foods, Inc., will survey progress in the frozen foods business, L. R. Boulware of Carrier Corp. will talk informally on air conditioning, and George Taubeneck, editor of *Air Conditioning & Refrigeration News*, will report on his recent trip around the world.

The program of technical sessions follows:

WEDNESDAY—DEC. 2

10:00 A.M. Aspects of Air Conditioning.
"Residence Cooling Investigations", Professor H. J. MacIntire, University of Illinois.
"A Review of Refrigeration and Air Conditioning Codes and Standards", Chester Lichtenberg, General Electric Co.
"Evaporative Cooling for Comfort", W. L. Fleisher, consulting engineer, New York, N. Y.

2:30 P.M. Thermal Problems.
"Moisture in Relation to Insulated Walls", Harvey B. Lindsay, president, Dry-Zero Corp.
"A Study of Heat Transfer in Unit Refrigerant Condensers Which Use Evaporative Cooling", Byron E. James, York Ice Machinery Corp.
"Air Conditioning Applied to Lithography", L. C. Weber, U. S. Bureau of Standards.
Report of Joint Committee—Glen Muffly.
L. R. Boulware—Informal Talk on Air Conditioning.

THURSDAY—DEC. 3

9:30 A.M. Jointly with A.S.M.E.
"Method of Computing Thermal Properties of Oxygen and Nitrogen", W. F. De Baufree.
"Review of Psychrometric Theory and Data", W. H. Carrier, Chairman of the Board, Carrier Corp.

2:30 P.M. Commercial Field.
"Brine Solutions in Truck Bodies", O. S. McGuffey.
"Beer Dispensing Methods", John Wyllie, Temprite Co.
"Freon 12 Thermal Expansion Valve Requirements", J. C. Bergdoll, product engineer, York Ice Machinery Corp.

FRIDAY, DEC. 4

10:30 A.M. Absorption Methods.
"Silica Gel in Air Conditioning", W. E. Stark, Bryant Heater Co.
"Commercial Absorption System", Glenn F. Zellhoefer, Williams Oil-O-Matic Heating Corp.
"Problems in Household Absorption System", Dr. W. R. Hainsworth, vice-president, Servel Corp.
"The Open Absorption System", Dr. A. A. Berestneff, Carrier Corp.

Equipment at Power Show

Latest reports from the Twelfth National Exposition of Power & Mechanical Engineering, to be held in Grand Central Palace, New York, N. Y., Nov. 30 to Dec. 4, give this classification of equipment on display: fuels, combustion equipment; refractories, steam-generating equipment; steam-distribution equipment; piping and fittings; prime movers, pumps and hydraulic equipment; electric generators and motors; electrical transmission, distribution control; power transmission; control apparatus and precision instruments; power-driven machinery; tools and machine tools; material-handling equipment; heating, ventilating, refrigeration, air-conditioning; lubricants; operation and maintenance material. Attendance this year is expected to exceed the 37,000 registered in 1934.

New England Power Men Assume New Duties

John B. Mahoney, for the past 24 years superintendent of the Western Division, New England Power Co., with headquarters at Shelburne Falls, Mass., and one of the best-known generating station executives in the Northeast, has been transferred to the Boston staff of New England Power Assn.

Henry A. Suprenant, assistant Western Division superintendent, New England Power Co., has been made superintendent, succeeding J. B. Mahoney. Mr. Suprenant joined the system in 1915, handling maintenance work in the Deerfield River plants, later becoming assistant superintendent of Plant No. 5 (Hoosac Tunnel), superintendent at Vernon, and division supervisor of operation. Harry L. Hurd, technical assistant, Western Division, becomes assistant superintendent in place of Mr. Suprenant. He "signed up" with New England Power Co. at Worcester in 1925 as a meter inspector, and later served as meter foreman for the Western Division. Philip W. Rancourt, supervisor of stations, Western Division, has been appointed superintendent of hydro and mechanical maintenance. He joined the system at the Vernon station in 1912 and has served as master mechanic, station superintendent at Vernon, and waterwheel and governor engineer for the Western Division.

"White Water" Surveys

"White Water" is a term used by the Division of Irrigation in its new job of predicting the late-season volume of irrigation water from high-mountain snow. For centuries the run-off of summer water has been predicted on the basis of snow depth. Such predictions were broadly erroneous because density, or water content, of snow, is the determining factor—not depth. Water content varies as much as 100%. High, dry snow is like feathers, shrinks away to mere drops of water.

Early in this century two Western educators: Dr. J. E. Church, of the University of Nevada, and Professor George D. Clyde, at the University of Utah, began to study snow fall, and showed that accurate predictions of late run-off could be made if *water content* were measured *at high altitudes*.

In Utah, for example, snow above 8,000 ft. is the exclusive basis of July and October water supply. Only 10% of the State's area is above 8,000 ft.

In 1934 the "white water" men predicted the most severe shortage ever recorded. Planting of all late crops was curtailed, with tremendous savings. Hydro-electric summer loads were checked against auxiliary power. A tie-up of river boats was anticipated.

This winter will be the second for the new snow survey service. Measurements begin in April. Including men regularly on the government payroll, 1,000 are engaged in the surveys in 11 Western states.

MEETINGS

American Society of Mechanical Engineers—*Annual meeting, Engrg. Societies Bldg., 29 West 39th St., New York, Nov. 30–Dec. 4. C. E. Davies, secretary.*

American Society of Refrigerating Engineers—*32nd annual meeting, Hotel Pennsylvania, New York, N. Y., Dec. 2-4. D. L. Fiske, secretary, 37 W. 39th St., New York, N. Y.*

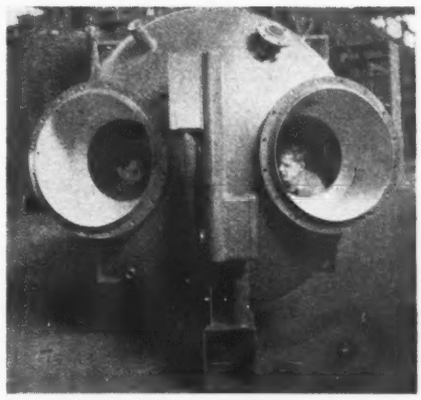
National Marine Engineers' Beneficial Assn.—*61st Convention, Jan. 25–30, Lee House Hotel, 15th and L Sts., Washington, D. C. A. L. Jones, secretary-treasurer, 313-316 Machinists Bldg., Washington, D. C.*

National Oil Burner & Air Conditioning Exposition & Convention—*March 15–19, Convention Hall of Commercial Museum, Philadelphia, Pa. Oil Burner Institute, New York, in charge. C. F. Curtin, secretary.*

Leipzig Fair—*Feb. 28 to Mar. 8, 1937. Spring Fair will be 1977th session in 700 years. 8,000 exhibits.*

Society for the Promotion of Engineering Education—*Fall meeting, Middle Atlantic Section, Columbia University, New York, N. Y., Dec. 5. All engineers interested in education are invited.*

Twelfth National Exposition of Power & Mechanical Engrg.—*Grand Central Palace, New York, N. Y., Nov. 30-Dec. 5. In charge Chas. F. Roth, International Exposition Co., Grand Central Palace, New York, N. Y.*



2-EYED MONSTER

But at first glance only—a closer examination shows it is the tank of a large oil circuit breaker laid on its side to assist the workmen. Snapped in the GE Philadelphia works, this view shows preparations for bushings and internal mechanism.

Welding Society Announces Evening Lecture Course

The New York Section of the American Welding Society has arranged with Brooklyn Polytechnic Institute to present this winter a series of lectures on the fundamentals of welding. The lectures will be given in the Institute, 99 Livingston St., Brooklyn, on Tuesday evenings at 6:45, beginning Nov. 10.

The course will comprise ten illustrated talks covering: Characteristics of the Welding Arc and Welding Flame, Metallurgy and Metallography of the Welding of Steel, Physical Properties of Welds, Welding in Engineering and Building Construction, Weld Inspection and Supervision, the Welding of Alloy Steels and Non-Ferrous Metals, the Economics of Welding, the Selection of Welding Processes. Speakers will include: S. C. Osborn, Wilson Welder & Metals Co.; G. V. Slottman, Air Reduction Sales Co.; J. C. Hodge, Babcock & Wilcox; G. E. Claussen, Brooklyn Poly-

technic Institute; Gilbert D. Fish, consulting engineer; E. R. Fish, Hartford Steam Boiler Inspection & Insurance Co.; A. B. Kinzel, Union Carbide & Carbon Research Laboratory; L. E. Abbott, Bell Telephone Laboratories; G. H. Holbrook, Federal Shipbuilding & Dry Dock Co.; J. H. Deppeler, Metal & Thermit Corp. Information may be obtained from the American Welding Society, 33 West 39th St., New York, N. Y.

OBITUARIES

L. C. Nichols, 58, electrical engineer in charge of the Transformer Section, Allis-Chalmers Electrical Division, Milwaukee, Wis., died recently. He joined Bullock Electric & Mfg. Co., Cincinnati, Ohio, in 1903, where he established its Transformer Division, absorbed in 1904 by Allis-Chalmers. In 1911 he was made chief engineer of the entire Bullock electric division, which he held until 1915, when the transformer business was moved to Milwaukee and enlarged and Mr. Nichols was advanced to his present post.

James A. Hall, 48, professor of mechanical engineering at Brown University since 1925 and one of the most prominent members of the profession in New England, died at the Jane Brown Hospital in Providence, R. I., Oct. 29. He was the author of many articles in the engineering press.

Charles H. Mitchell, 76, for many years an operating engineer at Dedham Ave. pumping station, Needham, Mass., died at a local hospital Nov. 3 as the result of a shock.

Thomas E. Penard, 58, assistant superintendent of the station engineering department of Edison Electric Illuminating Co. of Boston, died at the Cambridge (Mass.) City Hospital Oct. 27, following a shock sustained while on his way home from work. Mr. Penard was widely known in power-plant circles and had been identified with the design of the Edison company's electrical installations for many years. He entered the company's service as a draftsman in 1900, attaining his late post in 1931. For some time he was dean of the evening school of Northeastern University, Boston.

John J. Rattigan, 63, operating engineer at the Boston federal building and formerly a plant engineer at the Watertown, Mass., Arsenal, died of a heart attack Oct. 21.

SOCIETIES AND SCHOOLS

Engineers Council for Professional Development, Engineering Societies Bldg., 29 West 39th St., New York, N. Y., has taken formal action in accrediting engineering curricula in educational institutions in New England and Middle Atlantic states. Curricula in other schools of the country will be investigated during the coming year, and a complete list of approved institutions issued thereafter. No attempt was made to accredit institutions, but rather to accredit specific undergraduate curricula leading to engineering degrees.

The Engineers' Council for Professional Development received Oct. 22 $16,000 from Carnegie Corp. of New York through Carnegie Foundation for the Advancement of Teaching.

"Humanistic Content of Engineering Curricula" will be the subject of the meeting of the Middle Atlantic Section, Society for the Promotion of Engineering Education, at Columbia University, Dec. 5. Copies of the program may be secured from Dean J. W. Barker, School of Engineering, Columbia University, New York, N. Y.

PERSONALS

Prof. Comfort A. Adams of the Electrical Engineering Department, Harvard Engineering School, authority on electric welding and prominent consultant in utility and industrial fields for many years, has resigned from teaching to devote himself to professional practice. His business headquarters will be at the Edward G. Budd Mfg. Co., Philadelphia, Pa., and he will continue to reside at Belmont, Mass. Dr. Adams is a past president of the A.W.S. and A.I.E.E. He was the first chairman of the American Engineering Standards Committee. He was on Harvard's teaching staff for 45 years, serving as dean of the Harvard Engineering School in 1919, and as full professor of electrical engineering from 1906 until his resignation this fall. Among his clients has been Babcock & Wilcox, notably in connection with electric welding problems at the Boulder Dam generating station.

J. S. Allison, Jr., has been appointed Chicago district manager of the Refractories Sales Dept., Babcock & Wilcox Co., with offices in the Marquette Bldg., 140 S. Dearborn St. He was formerly manager of the High-temperature Insulating Dept., Building Products Division, Armstrong Cork Products Co.

J. L. Baker, formerly president of Baker Ice Machine Co., Inc., who retired some time ago, was honored by members of the Refrigerating Machinery Association at their annual meeting in Washington, Nov. 12. Mr. Baker collaborated with John Larsen in producing the first Baker compressor in 1905.

Leslie W. W. Morrow, for the past ten years editor of *Electrical World*, has been appointed general manager of the new Fibre Products Division of Corning Glass Works, Corning, N. Y. This division, in operation since May of this year, manufactures fibrous glass for insulation.

C. F. Bolles, after thirteen years with Public Service Electric & Gas Co., (N. J.) in the design and construction of outdoor switching and substations, has joined the New York office of Delta-Star Electric Co., Chicago, as sales engineer.

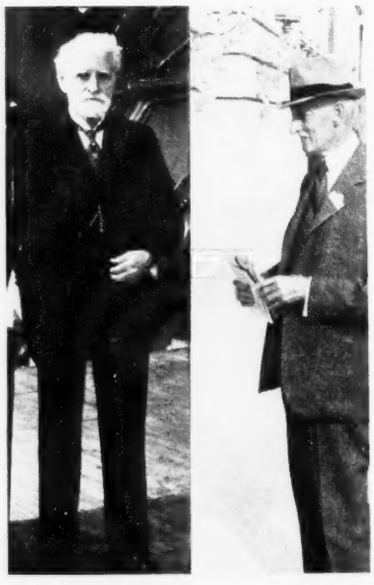
Thomas W. Drought has been elected vice-president of the New York Power & Light Corp. to succeed John L. Haley, who has been elected a vice-president of Niagara Hudson Power Corp.

Frank Malcolm Farmer, vice-president and chief engineer of Electrical Testing Laboratories, New York, has been elected chairman of the Engineering Foundation, research organization of the national engineering societies.

George L. Knight, vice-president in charge of mechanical operations, Brooklyn Edison Co., Brooklyn, N. Y., has been re-elected president of the United Engineering Trustees, Inc., joint agency of the four Founder Engineering Societies. Otis E. Hovey, consulting engineer, of New York, and D. Robert Yarnall, chief engineer of Yarnall-Waring Co., Philadelphia, were named vice-presidents.

Robert Jory has been appointed sales engineer of Riley Stoker Corp., Worcester, Mass., with headquarters at the New York office. He is a licensed professional engineer in both New York and New Jersey and has been associated with several prominent consulting firms.

Ambrose Swasey, chairman of the board, the Warner & Swasey Co., Cleveland, founder of the Engineering Foundation, past-president of the A.S.M.E. and honorary member of many American and foreign engineering societies, will receive the second Hoover Gold Medal at the A.S.M.E. Annual Dinner in New York, Dec. 2. He will be 90 Dec. 19.



Swasey Jacobus

Dr. David S. Jacobus, consulting engineer of Babcock & Wilcox Co., has been awarded the Morehead Medal for 1935 for his outstanding leadership in the formulation of codes and procedure which have made fusion welding acceptable. The medal was presented to Dr. Jacobus during the opening session of the 37th annual convention of the International Acetylene Association at Hotel Jefferson, St. Louis, Nov. 18.

HENRY METCALF HOBART, consulting engineer for General Electric Co. since 1911, was made the 1935 recipient of the Samuel Wylie Miller Memorial Medal of the American Welding Society.

LELAND D. WOOD, who has managed the municipal lighting department at Hudson, Mass., for the past fourteen years, and has been intimately identified with the application of diesel generating units in that station, has been made manager of the city lighting department at Norwich, Conn., succeeding C. W. Taggart. George D. Noiles, chief engineer at Hudson, has been made acting manager.

J. H. GALLOWAY, formerly sales manager for De La Vergne Engine Co., has become manager of the Kansas City, Mo., office of Nordberg Mfg. Co., Milwaukee, with Ambassador Hotel, Kansas City, as his address.

J. M. FERNALD, general manager of Baker Ice Machine Co., Inc., Omaha, Neb., was elected president of the Refrigerating Machinery Association at its annual meeting in Washington, Nov. 13.

FREDERICK R. FISHBACK, president of Electric Controller & Mfg. Co., Cleveland, Ohio, has been elected president of National Electrical Manufacturers Association. He has been with Electric Controller & Mfg. Co. since 1905.

W. W. WILLIAMS, formerly general sales manager of Babcock & Wilcox Tube Co., Beaver Falls, Pa., has been appointed general manager, and T. F. Thornton, formerly sales manager of the Detroit office district, has been appointed general sales manager.

THOR M. OLSON has been appointed sales manager of Ex-Cell-O-Aircraft and Tool Corp., Detroit, succeeding Wm. F. Wise.

H. W. HARMAN, for many years head of the Engineering and Research Dept., Stearns Magnetic Mfg. Co., Milwaukee, Wis., has been transferred to the Sales Dept. with supervision of the Purchasing Dept.

JOHN C. BRYAN has joined Foster D. Snell, Inc., 305 Washington St., Brooklyn, N. Y.

JOHN R. MCCLUNG, formerly assistant chief engineer of Pacific Power & Light Co., Portland, Ore., has been made assistant to the general manager.

ROGER MCWHORTER, chief engineer of the Federal Power Commission, who was injured seriously in an automobile accident some time ago, resumed his duties Nov. 9.

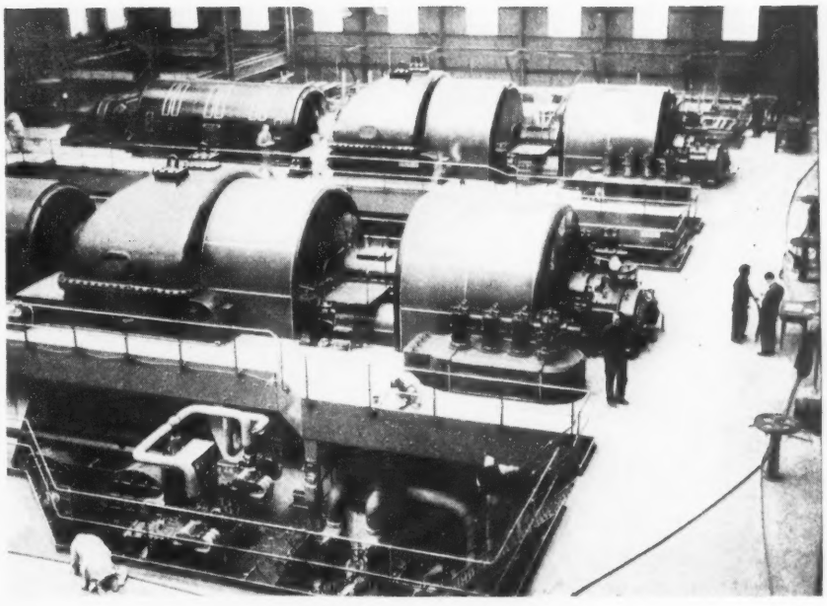
B. E. SIVYER, JR., has been appointed San Francisco office manager of the Chain Belt Co. to succeed the late G. E. Taylor.

HERMAN RUSSELL, president of Rochester Gas & Electric Corp., has been elected president of the American Gas Assn.

J. BRODIE SMITH, vice-president and general manager of Public Service Company of New Hampshire, was given a half-century service medal and testimonial parchment signed by 800 employees at a dinner in Manchester Oct. 26, in commemoration of his 50 years of constructive activity in the electric power industry. In his long career Mr. Smith has been intimately identified with the development of the network of steam and hydro plants forming this system. Congratulations were received at the dinner from Owen D. Young, chairman of the board, General Electric Co., and C. W. Kellogg, president of Edison Electric Institute.

LEON JOHN WILLIEN, operating gas engineer of Public Utility Engineering & Service Corp., Chicago, formerly Byllesby, Eng. & Management Corp., received Oct. 29 the Charles A. Munroe Award at the annual convention of the American Gas Assn. in Atlantic City, in recognition of his outstanding contribution in the general interest of the gas industry.

DAVID S. YOUNGHOLM, with Westinghouse Elec. & Mfg. Co. for the past 27 years, has been elected vice-president. He was formerly vice-president of the Westinghouse Lamp Company.



LONDON'S NEW STATION

Fulham, the first section of which was opened Sept. 26, has cost $18,750,000 thus far. When completed, its cost will be about $25,000,000. Two 60,000-kw. turbo-generators and six 3-drum, 200,000-lb. per hr. boilers form the first unit. Largest station in London, it will supply power to the whole of southeastern England.—*Globe-Fox.*

STRAWS

Pointing the way business winds blow

PUBLIC SERVICE ELECTRIC & GAS CO., Newark, N. J., announced a new peak demand Oct. 26 when load reached 552,200 kw. at 6 p.m. This exceeds by 11,700 kw. the previous maximum demand, which occurred in 1930. Normally highest demand occurs in December, so this record will probably be broken again before the end of the year.

PUBLIC WORKS DEPT., Rochester, N. Y., plans steam power house in connection with new municipal incinerator plant, with installation of waste heat boiler units, pumping machinery and accessories. Entire project will cost close to $400,000.

HEYWOOD WAKEFIELD CO., Gardner, Mass., has plans for steam power plant at furniture factory. Cost close to $35,000.

SOUTH

CORDELE DEVELOPMENT CORP., Cordele, Ga., recently organized, is at head of project to construct a local mill and steam power house, to be occupied under long-term lease for a knitting mill, by company whose name is temporarily withheld. Entire project will cost over $100,000.

VETERANS' ADMINISTRATION, Washington, D. C., will receive bids until Dec. 22 for boiler-plant equipment for institution at Lexington, Ky.

MIAMI, FLA., plans complete modernization of all existing pumping stations and power plants used for waterworks, with construction of a number of new plants. A 6-year program of expansion and improvements has been adopted, with $2,500,000 to be expended. About $3,000,000 will be used for extensions in water distribution and service facilities. William Sydow is public service director.

MANHATTAN LAUNDRY CO., 1346 Florida Ave., N. W., Washington, D. C., has plans for addition to steam laundry. Cost about $55,000 with equipment. Bedford Brown, 3428 North Glede Rd., Clarendon, Va., architect.

EDGEWOOD SHOE FACTORIES, INC., 16 Yonge St., S. E., Atlanta, Ga., a division of General Shoe Corp., 511 Gallatin Ave., Nashville, Tenn., plans boiler plant in 2-story shoe factory on Moreland Ave., Atlanta. Cost about $300,000.

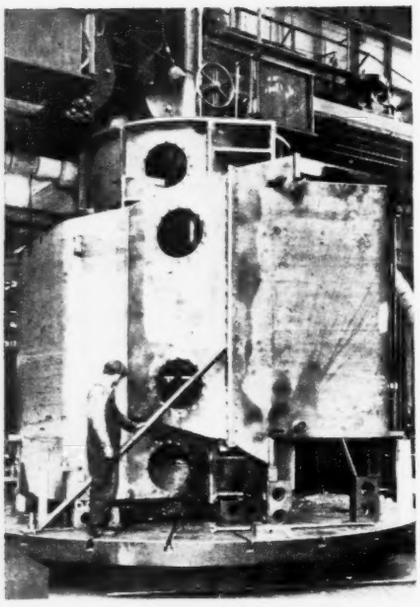
SHELBY, N. C., plans early construction of municipal power plant, including installation of three 1,050-hp. diesel units, with complete auxiliaries. Cost about $294,000, of which $132,300 is through Federal grant.

MIDWEST

LOGANSPORT, IND., contracted Baker Specialty & Supply Co., Logansport, for boiler unit and auxiliary equipment for municipal power plant, at $41,470.

BARBERTON, OHIO, plans electric-operated pumping plant and improvements in present pumping station on Wolf Ave., in connection with new sewage treatment works. Entire project will cost about $420,000.

OWENTON, KY., has approved bonds for $75,000 for municipal plant, and will have plans drawn soon.



EXHAUST HOOD

Exterior of an arc-welded, fabricated exhaust hood for a 25,000-kw. steam turbine being machined on a large boring mill in the G.E. Schenectady shops. The completed machine will be of the tandem-compound type.

NEBRASKA GAS FUEL CO., Lexington, Neb., will build welded steel pipeline from connection with main trunk line to Alma, Neb., for natural-gas transmission. Franchise secured. Entire project will cost $80,000.

JOHN D. FORSYTH, Niobrara, Knox County, Neb., chairman of Knox County Board of Supervisors, is at head of project to establish a new power and irrigation district in that area. Project will include a diversion dam on Niobrara River, hydroelectric generating station, transmission and distributing lines, with series of electric-operated pumping stations for water supply in district limits. Cost $1,400,000. Financing through Federal aid.

WEST LIBERTY, IOWA, plans extensions and improvements in municipal power plant, including installation of new diesel unit. Charles J. Mackey, town clerk, in charge.

NORTH LOUP PUBLIC POWER & IRRIGATION DISTRICT, Ord, Neb., E. H. Dunmire, manager, will take bids soon for two hydroelectric generating plants at Sioux Creek and at mouth of Gravel Creek, with about 50 miles of canals. Project will cost about $2,000,000, of which $1,600,000 through Federal aid. Black & Veatch, 4706 Broadway, Kansas City, Mo., consulting engineers.

MAX AND JACOB COHEN, South St. Paul, Minn., meat packers, plan steam power house at new 1-story and basement plant at 36th & J Sts., Omaha, Neb., where site has been acquired. Project will cost about $160,000.

NIOBRARA RIVER DAM of Northern Nebraska Power Co., 7 miles south of Spencer, Nebr., failed Sept. 24. A 150-ft. section of the 1,800 ft. dam went out.

FOREST CITY, IOWA, will take bids soon for municipal power plant. Fund of $165,000 through Federal aid. Young & Stanley, Inc., Muscatine, Iowa, consulting engineer.

SOUTHWEST

LUCY PETROLEUM CO., Dallas, Tex., has contracted Dewey & Ross Engrg. Co. for a 6-in., 20-mile pipeline to be Lindewelded. Terminals are Talco and Mt. Pleasant, Tex.

CROSBY & MORAN, INC., Tulsa, Okla., has awarded J. R. Stewart Construction Co., Tulsa, a 6- and 8-in. 4-mile laterial gathering pipeline and 4½-mile, 16-in. transmission line, all to be Lindewelded, to supply natural gas to the Fittstown gasoline plant of Crosby & Moran.

CITIES SERVICE GAS CO., Bartlesville, Okla., is planning to lay 7½ miles of 6½-in. gas line near Mattfield Green, Kans., using Lindeweld methods.

CONTINENTAL OIL CO., Ponca City, Okla., plans group of large air-compressor stations at new carbon-black manufacturing plant in vicinity of Dumas, Tex., where tract of land has been acquired. Plant will have capacity of 70,000,000 cu. ft. of natural gas per day; welded steel pipeline will be built from wells in Hutchinson County, Tex. Project will cost over $1,000,000. Shamrock Oil & Gas Co., Tulsa, Okla., is interested.

LITTLE ROCK, ARK., plans modernization of pumping plant, including new electric-operated pumping units and accessory equipment. Cost over $60,000. Burns & McDonnell Engrg. Co., 107 West Linwood Blvd., Kansas City, Mo., consulting engineer.

HOUSTON NATURAL GAS CO., Petroleum Bldg., Houston, Tex., plans welded steel pipeline from connection with present main trunk line to municipal limits at Bishop, Tex., with installation of distributing system. Franchise granted.

CRESCENT, OKLA., has plans under way for a municipal gas plant. Fund of $27,000 voted. Bids soon.

WHITE DEERE PIPE LINE CONSTRUCTION CO. will build 9 mi. of various sized Lindewelded pipe for a natural gasoline plant of Phillips Petroleum Co., near Edmond, Okla.

WEST

IMPERIAL ICE & DEVELOPMENT CO., El Centro, Calif., has authorized rebuilding of local ice-manufacturing plant, recently destroyed by fire with loss of about $100,000, including equipment. Gay Engrg. Co., 2650 Santa Fe Ave., Los Angeles, Calif., engineer.

SAN DIEGO CONSOLIDATED GAS & ELECTRIC CO., San Diego, Calif., has purchased a 35,000-kw. steam turbo-generator for Station B, adding 37% to present installed capacity and permitting removal of some obsolete units. Overload capacity will be 43,750 kw. Two 200,000-lb. per hr. boilers are also being added in a new boiler room, increasing steaming capacity 60%. Cost of the new machinery and equipment will be $2,220,000.

SMITH CANNING CO., Athena, Ore., plans boiler plant for steam supply for processing and heating at new vegetable canning factory at Pendleton, Ore., where site is being selected. Cost about $60,000. Albert T. Smith is head.

DEPT. OF INSTITUTIONS, Sacramento, Calif., has authorized cold-storage and refrigerating plant at Camarillo State Hospital, Ventura County. Work will be carried out in conjunction with other buildings at institution, entire project to cost over $200,000. George B. McDougall, Public Works Bldg., Sacramento, state architect.

J. N. HUBER CO., Lancecreek, Wyo., is building a 2-mile pipeline to carry gas to its carbon black plant; the 10-in. line, all Lindewelded, will replace an 8-in. line now in service.

LA MESA, LEMON GROVE AND SPRING VALLEY IRRIGATION DISTRICT, La Mesa, Calif., plans electric-operated pumping plant in connection with flume replacement project now under way. Station will cost about $40,000 with equipment.

SEWARD, ALASKA, has bid from R. J. Sommers, Juneau, Alaska, for municipal hydro-electric power plant, including penstocks, waterwheels and generators, with transmission line to municipality, at $278,000, and is scheduled to secure award. Financing through Federal aid. Hubbell & Waller, Alaska Bldg., Seattle, Wash., consulting engineers.

CHEYENNE, WYO., plans electric-operated pumping plant with several units, and power line for station service. Entire project will cost about $80,000.

ILLINOIS PIPE LINE CO., Casper, Wyo., an interest of Ohio Oil Co., Findlay, Ohio, has contracted White Deer Construction Co., Oklahoma City, Okla., for 6-in. welded steel pipeline from Lusk, in Lance Creek, Wyo., to Fort Laramie, Wyo., about 40 miles, for crude-oil transmission. Pumping stations along route for booster service. Cost about $250,000.

SIERRA MOUNTAIN WATER CO., 410 East Market St., Stockton, Calif., has applied for permission to use water from Cosumnes River, a tributary of Mokelumne River, Amador County, for proposed hydro development, on site being selected. Initial station will have a rated capacity of 13,800 hp. Cost reported over $500,000.

BRIGGS LEMON ASSN., Santa Paula, Calif., plans boiler house at citrus fruit-packing plant. Air compressor station will be installed. Entire project will cost about $175,000. Roy C. Wilson, Santa Paula, is architect.

WASHINGTON LAUNDRY CO., 1165 Eastlake St., Seattle, Wash., has plans for 1-story boiler house. H. H. Lewis, 322 Columbia St., architect.

SHELL OIL CO., San Francisco, Calif., a subsidiary of Shell Union Oil Corp., New York, N. Y., has approved plans for four pumping plants in Bakersfield and Kettleman, Calif., with extensions and improvements in six existing stations. Entire project will cost about $500,000.

ROGUE-ELK LUMBER CO., Medford, Ore., H. O. Harwood, president, recently organized, plans steam power house at 60,000-ft. per day lumber mill. Entire project will cost close to $65,000.

GLENWOOD SPRINGS, COLO., is considering new municipal electric power plant and will have estimates of cost made soon.

AZUSA ORANGE CO., Azusa Ave., Covina, Calif., has plans for pre-cooling and refrigerating plant at fruit-packing house, 42x70 ft., to cost close to $35,000.

KENNEWICK CUSTOM CANNERY, Kennewick, Wash., plans steam power plant for

proposed canning plant. Work scheduled to begin early in 1937. Cost over $45,000. Willard Campbell is head.

EXCELSIOR UNION HIGH SCHOOL DISTRICT, Norwalk, Calif., has plans for 1-story steam plant at high school on Pioneer Blvd., for central heating service. Financing through Federal aid. T. C. Kistner, Architects' Building, Los Angeles, Calif., architect.

SWAYNE LUMBER CO., Oroville, Calif., plans steam power house in connection with rebuilding of portion of lumber mill and plant, recently destroyed by fire. Loss over $200,000.

WINNEMUCCA, NEV., has secured Federal appropriation for municipal electric plant, to include two 300-hp. diesel units. A distributing system will be installed. Bids to be asked soon. Cost about 120,000.

THE DALLES, ORE., is projecting plans for a power dam and municipal hydro plant on Columbia River, near city. Cost close to $20,000,000. Proposed to arrange fund through Federal aid. The Dalles Chamber of Commerce is active in project.

BUREAU OF RECLAMATION, Denver, Colo., contracted Fairbanks, Morse & Co., Chicago, Ill., for pumping machinery and accessory equipment for pumping plant for irrigation project, at $32,354 (Specifications 819-D).

WILLIAM E. HUGHES ESTATE, Denver, Colo., has contracted J. H. Gates to Lindeweld 15½ miles of 4½-in. oil line from Abandoned Peak, Colo., to Chama, N. M.

FREDERICK, COLO., contracted Acason-Miller Diesel Sales Co., 1300 Glenarm Place, Denver, Colo., for two diesel units.

IMPERIAL IRRIGATION DISTRICT, El Centro, Calif., plans series of four hydroelectric generating plants along route of All-American Canal, now in course of building. The Bureau will construct substructures for power houses concurrently with work on channel at Drops Nos. 2, 3, 4 and 5, at estimated additional cost of $1,075,000. Drops will provide for total installed capacity of 54,200 kva., the first two sites to have stations of 12,000-kva. each, Drop No. 4 to have a plant of 24,000-kva. rating, and Drop No. 5, 6,200-kva. capacity. Two potential power locations along the canal, Drop No. 1 and Pilot Knob Drop, will not be developed for hydroelectric station service at this time.

BOARD OF COUNTY SUPERVISORS, Flood Control District, 205 South Broadway, Los Angeles, Calif., will receive bids until Nov. 4 for heavy-duty valves for outlet service at San Gabriel Dam No. 1. Cost estimated at $1,000,000. C. H. Howell, flood-control engineer for board.

WESTERN GAS CO., El Paso, Tex., is completing surveys for new 16-in. welded-steel pipeline from point near Jal, N.M., to El Paso, for natural-gas transmission. Also for new 8-in. welded steel pipeline for similar service from Ajo to Phoenix, Ariz., about 80 miles, with compressor plant of 3,000 hp., at Douglas, Ariz. Entire project will cost about $1,000,000.

STATE HOSPITAL DEPT., Sacramento, Calif., plans installation of 5,000-sq.ft. boiler at State Hospital, Camarillo, Calif. Also will install water-pumping station. Cost about $45,000. Bids soon. George B. McDougall, State House, Sacramento, state architect.

NEWPORT BEACH, CALIF., plans three underground electric-operated pumping plants in new sewage system. Project cost about $300,000, of which $152,000 through Federal aid R. L. Patterson, city engineer.

FOREIGN STRAWS

VANCOUVER GENERAL HOSPITAL, Vancouver, B. C., is rebuilding its power plant. At the present time the Vancouver Iron Works is installing the new boiler and the Combustion Engineering Corp. is installing an automatic stoker.

EDMONTON, ALTA., Can., City Commissioners are receiving applications for the position of superintendent of municipal power plant, a 21,000-kw. steam generating plant which to be extended in the near future.

CHIEF ELECTRICAL ENGINEER, QUEEN VICTORIA BUILDINGS, George St., Sydney, Australia, is preparing plans and will call tenders in October for extensions to the boilerhouse plant and Bumeran Electricity Station. Total cost, $75,000. The plant is owned by municipality of Sydney, Australia.

HAMILTON COTTONS CO., LTD., Hamilton, Ont., having plans for boiler room extension, will be in market for additional equipment.

DR. H. LOEFFLER, 66 Victoria St., S.W. London, England, is preparing plans for a pulverized fuel-fired boiler for Trebovice, Czechoslovakia. The boiler will have normal output of 140,000 lb.; maximum output of 165,000 lb.; temporary peak output of 175,000 lb. of steam at 1,900 lb. and 935 deg. F.

HALIFAX, CANADA, is planning to install a modern heating unit in the new Provincial Building which will also be able to heat the historic Parliament House. The plant will include three large boilers and four turbo-generators. Department of Public Works in charge.

WINNIPEG, MAN., will install a 1,000-sq.ft. automatic boiler at Assinboine Park Conservatory.

CONTRACT for fabrication and erection of a new wood-stave siphon at the Barriere power plant of the B.C. Electric Railway Company near Kamloops, B. C., has been placed with Canadian Wood Pipe & Tanks, Ltd., 550 Pacific St., Vancouver. The siphon will consist of about 1,230 ft. of 72-in. pipe.

CONSOLIDATED MINING & SMELTING CO. is erecting a high concrete dam at Long Lake, B. C., to provide about 10,000 acre-ft. of water, and provide company power. The same company is surveying potential power sites on rivers that flow into the north side of Lake Athabaska, as well as falls on the Grease River and the Old Man River.

THE BOARD OF COMMISSIONERS of the Municipal Home, St. John, N. B., are planning to have automatic stokers installed shortly. Bids will be called for soon.

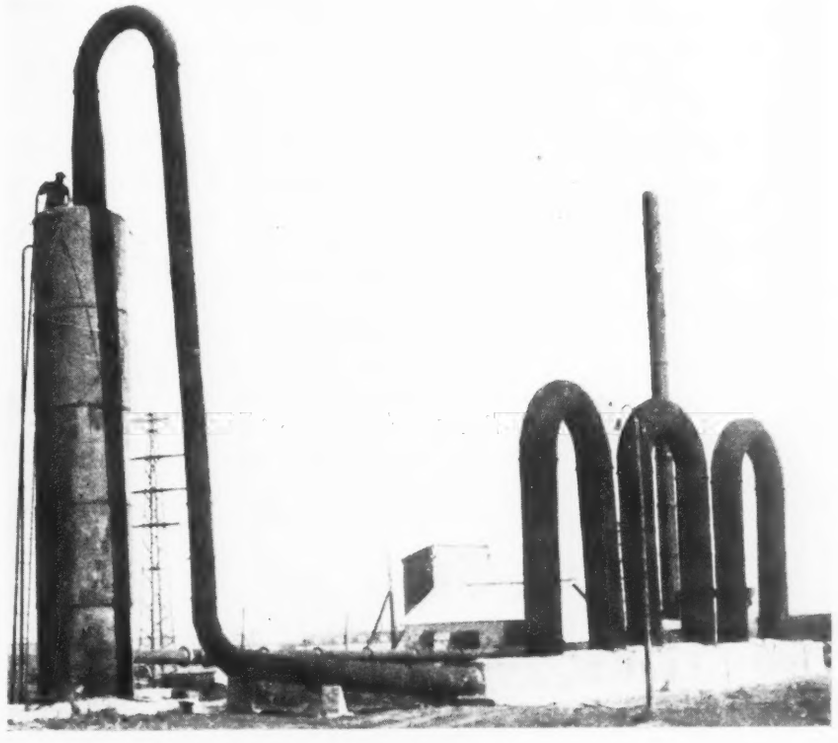
DOMINION STEEL & COAL CORP., Montreal, Que., has awarded a contract to Babcock-Wilcox, Goldie & McCulloch, Ltd., Galt, Ont., for equipment for two large steam-generating units.

GOLD MOUNTAIN MINES, LTD., near Hedley, B. C., lost its diesel plant recently by fire. A new plant to cost about $7,000 will be installed immediately.

GRANBY CONSOLIDATED MINING, SMELTING & POWER CO. is considering building its own power plant for its British Columbia mine. Headquarters are in New York.

MAN-MADE GAS UNDERGROUND

Russia is mining gas instead of coal, by burning the fuel underground and piping the gas to surface tanks. Air and steam are fed down to the coal, loosened by blasting, and the burning produces 300-B.t.u. per cu. ft. gas. Experiments are now under way with methods not requiring blasting.—*Sovfoto.*



30 DAYS HATH . . .

Budgets, like weather, are pretty hard to control. Come January 1, business executives begin to okay or reject expenditures for the next year—and what isn't allowed for on those budgets doesn't get done.

All this means that along about now, you and I should be finishing our figuring on what we'll need for next year. It probably would be better for us if the fiscal year would start in April—that at least is the time when it becomes possible to refurbish and change the heating equipment, but executives expect to approve or reject long before that. Misfortune it may be, but such misfortunes are often blessings in disguise—remember that the dog without a tail has no fear of a tin can. If you can get approval now, all the problems of ordering, specifying and delivery will be over by the time you're ready to go ahead with the changes.

And in some ways, a wake-up date like January 1 is an advantage—it makes you do some long-range planning that otherwise you'd forget. I remember once my dad had a horse that fell sick, and nobody could cure him. He just went right on dying—nothing anybody could have done would have made him any deader. So finally Dad decided to give him half a pound of salts, figuring it certainly couldn't do the horse any harm. But then, says Pa, "Thunder I might as well go the whole hog. I'll give him a pound, because anything that happens to him will be an improvement." Well, sir, the results were surprising. When the horse got over his astonishment, he got up and went to work, and he lived another ten years of healthy, useful life.

Maybe that sounds a mite overdrawn, but it makes my point—a good clean-up once in a while puts you in better condition to get somewhere. So, go on, be whole hog! Figure out what you'll need, some convincing arguments to back it up if and when asked, cross your fingers, and send it in.

Caution is all right in some places, but sometimes the best way to get results is to get a little upset and emphatic about it. If you've got to blow up, and can figure when, go ahead and blow—and remember you might as well blow up like a powder magazine, not like a penny firecracker. The first kind gives a lot more self-satisfaction and is a lot more impressive. If somebody objects to blowing up, he's going to object just as much one way as another—and when you have objectors in high places, its just exactly like being bankrupt—you might as well be bankrupt for a million dollars as for five. You can't pay either one.

So, remember the budget, to prepare it in time.

George Edwards

GEORGE EDWARDS,
Engineer